AUGUST, 1959

Welding Journal

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VOLUME 38 • NUMBER 8 • AUGUST 1959

Welding Journal

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PRESS-TIME NEWS ...about ...People ...Welding ...Products

Cox and Mullen Elected to RWAA Posts

At their Third Annual Meeting held at the Detroit Yacht Club, June 2nd, members of the Resistance Welding Alloy Assn., elected James C. Cox AWS president to succeed J. A. O'Grady AWS of Weldaloy Products Co.

Mr. Cox, who is president of the S-M-S Corp. of Detroit, is also chairman of the Association's standards committee which is actively engaged in developing a new numbering system for electrodes and electrode holders. In addition, he serves as chairman of the electrode subcommittee of the American Standards Assn.'s sectional committee on resistance welding machines and equipment.

Mr. Cox is also a member of the Engineering Society of Detroit and serves on the executive committee of the Detroit Section of the AMERICAN WELDING SOCIETY.

RWAA vice-president H. A. Mullen AWS is manager of the resistance welding department of Ampco Metal Inc. of Milwaukee and has been affiliated with them for the past 14 years. Prior to that, he was supervisor of welding control and development for the Chemical and Metallurgical Division of the Ford Motor Co.

Mr. Mullen has been active in RWAA since its organization and serves on the standards committee. He has also been a member of the AWS and the ASM for the past twenty years.

X-ray Spectrography School

X-ray Spectrography will be the subject of the 34th Norelco X-ray School according to an announcement by the Instruments Division Philips Electronics, Inc., Mount Vernon, N. Y.

Sessions will be held at the Sir Francis Drake Hotel, San Francisco, during the week of Aug. 31–Sept. 4, 1959. Registration for the course is open to chemists, metallurgists, physicists, production supervisors, quality control engineers and others interested in rapid, accurate, nondestructive methods of analysis.

Monday through Thursday, the meetings involve extensive classroom and laboratory work. On Friday, guest speakers discuss interesting application problems which are encountered in specific industries. Participants have ample opportunity to discuss their own problems and to become familiar with all types of equipment. There is no registration fee.

Nicholson New Linde President

William B. Nicholson has been appointed president of Linde Co., Division of Union Carbide Corp.

Mr. Nicholson became associated with Linde in 1935 as an engineer in the development laboratory at Newark. Following several years of experience in the sales organization, he returned to development work and was made manager of development in 1956, vice-president—gas products in 1958, and vice-president early in 1959. He received his B.S. degree from Georgia Institute of Technology and his M.S. degree from the University of Michigan. He succeeds William M. Haile, who has been elected a vice-president of Union Carbide Corp.

William B. Nicholson

Mrs. Andre First Woman to Receive Welding Engineering Degree

The first woman in the United States ever to earn a bachelor's degree in welding engineering graduated in June from Ohio State University.

Mrs. Jane R. Andre, 29, of Columbus, Ohio, graduated in the top quarter of her class and hopes eventually to become a research engineer in nondestructive testing. She already has completed some graduate courses and plans to work toward a master's degree and a Ph.D. in engineering.

Mrs. Andre decided to become an engineer because she was "fascinated with the engineers' dedication to their work," she explained.

The engineering student recently was elected a member in the Pi Mu Epsilon national honorary mathematics society. She also is a member of the American Society for Metals, the Society for Nondestructive Testing, and the American Society for Testing Materials and a member of the student chapter of the AMERICAN WELDING SOCIETY.

Mrs. Andre is the mother of a 10-year-old son, Jon. She lists her hobbies as dressmaking, photography and swimming.

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1959 AWS NATIONAL FALL MEETING

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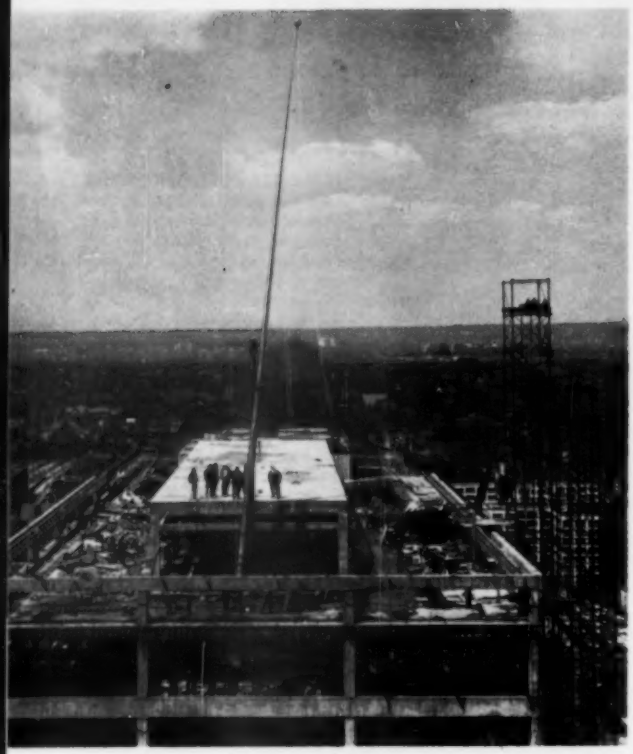
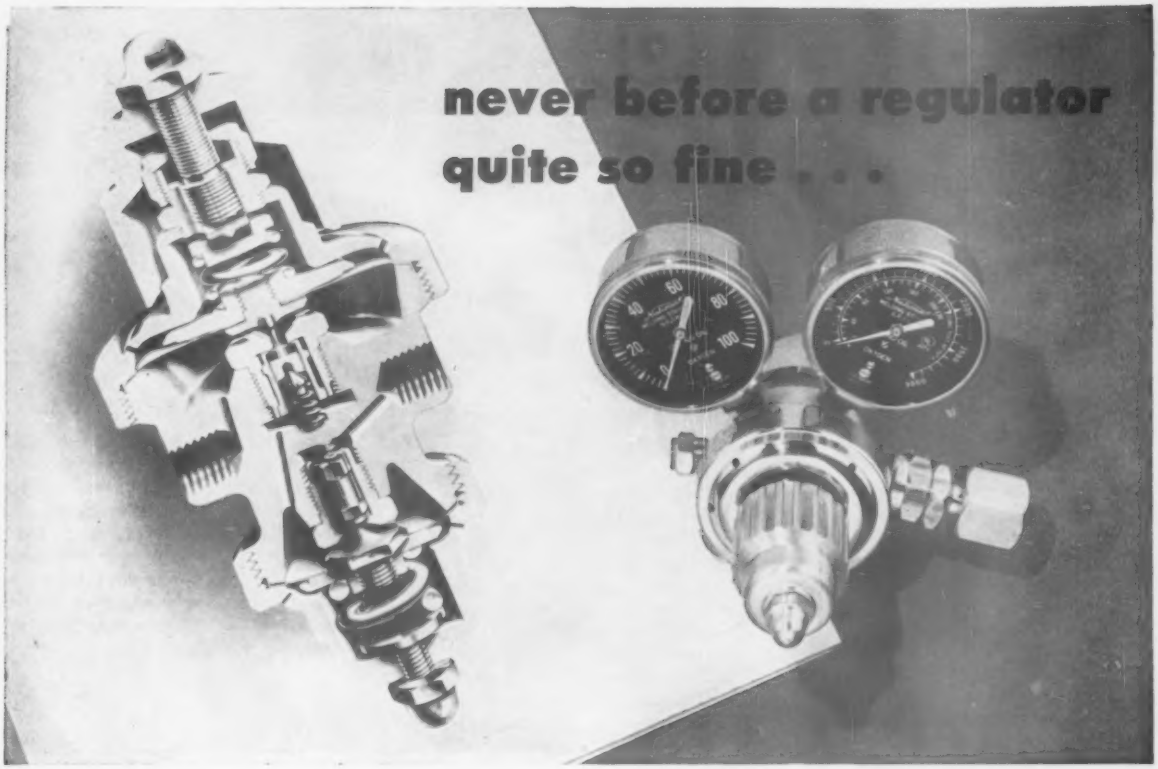


A 99-ft stainless-steel flagpole is shown at left being lowered into its socket atop the 24 story Prudential Plaza Building now under construction in Newark, N. J. The hollow pole fabricated by American Flagpole Co., Bronx N. Y., is built of welded sections, and tapers from 14 in. in diameter at the base to 4 in. at the top

High above the streets of Honolulu, statehood for Hawaii is proclaimed by a sign attached to the famed "pineapple" elevated tank, a landmark of the island for more than three decades. The colorful welded water tower, which has a capacity of 100,000 gal, was built by Chicago Bridge & Iron Co. in 1927 for the Hawaiian Pineapple Co.

This 28-ton compound steel casting, fitted together and welded with nearly one mile of welding wire, is one of two such units recently shipped from the Ellicott Machine Corp., Baltimore to Indonesia. It is a "bucket idler" for mounting on the dredging ladder of a placer dredge excavating tin-bearing sand and gravel from the off-shore deposits



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WORLD-WIDE WELDING NEWS

By Gerard E. Claussen

EAST GERMANY

Alloyed Fluxes Developed for Submerged-arc Welding

The fundamentals of designing sintered alloy-containing fluxes for submerged-arc welding are described by P. Beyersdorfer of the Glass Technical Institute in *Schweisstechnik* (Berlin) **9**, 1959. For steels which require relatively small quantities of alloying elements, such as 1% Cr - ½% Mo, alloying additions are introduced to the flux as oxides. Ferroalloys are sintered into the flux for the hard-surfacing alloys which require 10 to 15% of the alloying elements to be supplied by the flux. The recovery of alloying elements increases in direct proportion with the current density in the electrode.

FRANCE

New Method Developed to Clad Stainless Steels

The welding of clad steel and the cladding of vessels with stainless-steel sheet are discussed in the December 1958 issue of *Soudages et Techniques Connexes*. A method known as Rostenit is being used to sheath objects in thin stainless steel, 0.020 to 0.040 in. thick. First, stainless-steel strips are secured to the object. The sheets are then spot welded to the strips which also serve as backing for the final step of tungsten-arc welding the edges of the sheets together.

DR. GERARD E. CLAUSSEN is associated with Arcrods Corporation, Sparrows Point, Md.

Welding Engineers Meet in Paris

At the January 29th meeting in Paris of the French Society of Welding Engineers, L. deJessey was named president for 1959. J. Moreau-Desfarges and Mario Sciaky were made Chevaliers of the Legion of Honor. In electing five new members to the Administrative Council, the society noted a membership increase during 1958 from 1219 to 1257. 30,000-franc prizes were awarded to two graduates of the College of Engineering who compiled the highest scholastic records. It was also pointed out that the groups exhibiting the greatest activity within the Committee on Coordination of Welding Research were weldability, nondestructive and fatigue testing, education and resistance welding.

French Welding Industry Comes of Age

The welding industry in France has been growing at the rate of 20% per year, reaching a sales volume in 1957 of 20 million francs (Table 1), according to Secretary General Laville of the Associated Manufacturers of Welding Equipment. As reported in the January 1959 issue of *Soudage et Techniques Connexes*, M. Laville cited the welding speeds attained in the Sahara pipe lines—2½ miles per day on 4.9-in. diam pipe and 1¼ miles per day on 25.6-in. pipe—as examples of advancement. M. Laville presented his remarks at a recent meeting in Paris where a movie, "The Welding Age," was shown.

Table 1—Growth of the French Welding Industry

Year	Consumption of rolled steel, tons	Consumption of mild-steel covered electrodes, lb	Number of manual arc-welding machines	Acetylene production, cu ft	Oxygen production, cu ft
1938	3,500,000	9,600,000	1,800	120,000,000	760,000,000
1952	7,900,000	56,000,000	9,700	275,000,000	2,400,000,000
1956	10,500,000	75,000,000	17,000	330,000,000	3,200,000,000
1957	12,500,000	82,000,000	23,200	365,000,000	3,400,000,000

ITALY

Large Welding Positioner Described

One of the world's largest positioners for use in automatic welding is described by officials of the Calzoni firm of Bologna in the October 1958 *Rivista Italiana Della Saldatura*. Containing a 13-ft diam table, the positioner completes one revolution in three minutes with a weight of 35 tons in any position from 0 to 90 deg.

JAPAN

Japanese Welding Team Tours United States

In April a 10-man team of welding specialists from small businesses in Japan toured the United States under the joint sponsorship of the Japan Productivity Center, the International Administration and Training With Industry. During the team's visit to this country a booklet was circulated which outlined the growth of welding in Japan. Welding had its start in 1904 when repair welding of steel castings was practiced with the carbon arc. The booklet stated that most present-day arc welding is done by a-c, with several thousand transformers manufactured each month. Of the 80,000 tons of electrodes produced in 1957, 58% were of the ilmenite type. It was interesting to note that the Tokyo Metropolitan Industrial Research Institute along with several private schools offer training courses in practical welding for boys. Another statistic revealed that $3 million worth of resistance-welding machinery was manufactured in 1957.

Results Published on Weldability Tests

The results of cooperative research on weldability tests were published by Commission 9 of the Japanese Institute of Welding.

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9/16- by 2-5/16-in. torch head permits welding in hard-to-reach areas as small as 3 in. in diameter. Total torch length is under 7 inches.

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Weight —
with short cap: 3.3 oz.*
with medium cap: 3.5 oz.
with long cap: 3.6 oz.

Length overall — 6⅞ in.

Length of Torch Head —
with short cap: 2-19/64 in.*
with medium cap: 3-9/32 in.
with long cap: 7-5/16 in.

Maximum Handle Diameter — ¾ in.

Maximum Head Diameter — 9/16 in.

Service Lines — 12½ or 25 ft.

*Torch is supplied with medium cap for 3-in. electrodes. Short cap for 2-in. electrodes and long cap for 7-in. electrodes are available as accessories.

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Notch, crack-propagation, weld-ductility and weld-cracking tests were performed on five Japanese steels and several covered electrodes. Although most of the tests are well known in the United States, some of them are definitely new. For example a weld bead was deposited below the notch of a Van der Veen specimen. This ductile weld metal arrested crack propagation. In nearly all of the tests a steel containing 0.15% C, 0.08% Si and 0.95% Mn, gave the best performances, while the poorest results were obtained from a 0.17% C, 0.50% Si, 1.34% Mn steel. CCT diagrams were given for these steels.

SOVIET UNION

World's Welding Literature Abstracted

The January 1959 issue of *Svarachnoe Proizvodstvo* announced a new monthly abstract journal covering the field of welding theory, welding processes, applications and allied processes. About 300 to 400 publications throughout the world will be abstracted.

Boom Expected in Welded Pipe Lines

Russia consumed 1.05×10^{12} cu ft of fuel gas in 1958. Consumption is expected to rise to 5×10^{12} and 10×10^{12} by 1965 and 1970, respectively. To meet this consumption 16,200 miles of gas pipe line and 15,000 miles of oil pipe line must be laid by 1965. This and related work involves 100 million highly stressed welded joints, and four million man-days. In 1957, 56% of welded pipe construction in Russia was by the submerged-arc process, 35% by manual-arc welding and 9% by resistance welding.

Fatigue Tests Produced on Electro-slag Welds

Reversed-stress fatigue tests were made on specimens 8 in. in diam cut from electro-slag welds in cast steel containing 0.28 to 0.43% C, 0.59 to 0.73% Mn and 0.15 to 0.30% Si. The base metal had a fatigue limit at 10 million cycles of 10,500 to 15,600 psi. The weld metal contained 0.17 to 0.26% C, 1.01 to 1.22% Mn and up to 0.05% Si, and had a fatigue limit of over 10,500 psi, as welded.

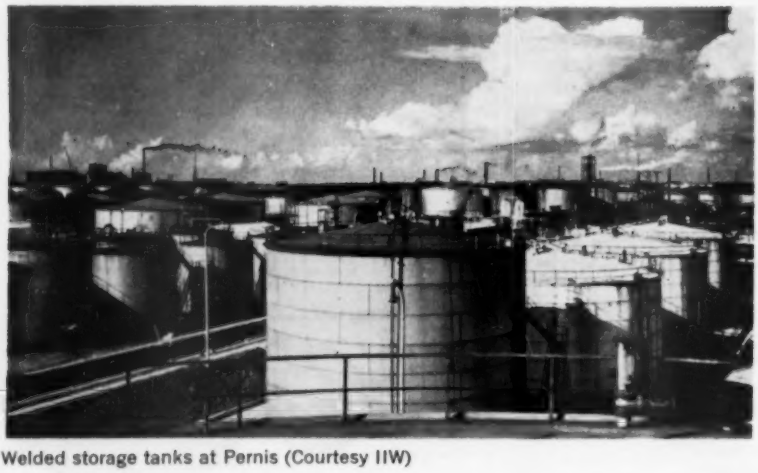
Aluminum Welds Studied

The heat-affected zone of welds in an aluminum alloy containing 5 to 7% Zn, 1.8 to 2.8% Mg, 1.4 to 2.0% Cu, 0.2 to 0.6% Mn and 0.1 to 0.25% Cr was studied with the aid of unwelded samples heated and cooled under the same conditions as in welding. The zone heated to 1110–1200° F had the poorest mechanical properties, and should be made as thin as possible by selecting a welding process involving low heat input and rapid cooling.

Formulas Calculated

A formula for calculating the efficiency of transfer of alloying elements from an electrode covering to the weld metal is given and is applied to the transfer of manganese in the presence of carbon dioxide evolved from coating constituents. The calculation of heat efficiency in gas pressure welding bars 1 to 3 in. in diam is explained. Graphs show temperature distribution along the bar.

NETHERLANDS



Welded storage tanks at Pernis (Courtesy IIW)

SWITZERLAND

Geneva Meeting Records New Reactor Welding Techniques

The latest welding techniques in all aspects of reactor construction are discussed by Ruge in the February 1959 issue of *Schweissen und Schneiden*. This article is a summary of results of the second atomic conference in Geneva.

WEST GERMANY

CO_2 Welding in Wide Usage

There are about 500 CO_2 welding outfits in operation in West Germany, according to the January 1959 issue of *Schweissen und Schneiden*. An estimated 18 million cu ft of CO_2 is consumed per year.

Title of Chief Welding Engineer Considered

A plan is afoot by the West German Welding Society, (described by H. Koch in the January 1959 issue of *Schweissen und Schneiden*), to establish the title "chief welding engineer" in addition to the title "welding engineer." The welding engineer receives his title on completion of a five-week course at least one year after receiving a degree from an engineering school. The title "chief welding engineer" would be conferred on completion of six months of study in schools specified by the society. The course of instruction includes 2 weeks gas welding, 2 weeks arc welding, 6 weeks welding engineering, 4 weeks materials testing, 8 weeks welding design, 2 weeks welding processes and apparatus and 2 weeks welding fabrication.

Secondary Current Measured in Resistance Welding

The measurement of effective current in the secondary circuit in resistance welding is accomplished by a Rogowski yoke, according to a West German engineer, E. Rohloff, in the January 1959 issue of *Schweissen und Schneiden*. A description of a method accompanied by calibration curves is given which takes into account partial rectification.

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NAVCO research into welding techniques and materials resulted in the selection of ATOM·ARC All Position Iron Powder Low Hydrogen alloys for handwelding of pipe fabrications and for field erection. The X-ray quality of ATOM·ARC weld metal eliminates needless rework. The flat, smooth bead contour makes slag removal easy, requires no costly and time consuming chipping and grinding, allowing weldors more time for welding. Even finish grinding of the final pass is eliminated. These cost saving properties of ATOM·ARC electrodes are amplified by the fast deposition rate achieved from the iron powder type coatings.

These are the facts NAVCO found in their search for better materials for high quality piping . . . facts which prove ATOM·ARC Iron Powder Low Hydrogen Alloys produce superior piping products. For your free copy of an informative and revealing report to piping contractors, write to:

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Editorial

Tack welding cast iron cones to carbon steel vortex tubes of gas scrubber. Ni-Rod "55" Electrodes make ductile, crack-free joints. Scrubbers made by The Aerotec Corp., Greenwich, Conn.

Weld cast iron to carbon steel...no preheat... no cracking...with Ni-Rod "55" Electrode

Joints were cracking up – between cast iron cones and carbon steel tubes in gas scrubbers like this one.

Welds made with carbon steel electrodes were just too brittle. They cracked when slag was chipped away. They sometimes broke entirely from rough handling in shipping.

Then – Aerotec weldors switched to Ni-Rod "55"* Electrodes, specially developed by Inco for welding cast irons. And what a difference – no more cracked welds . . . no more preheating . . . good penetration. And Aerotec finds that with Ni-Rod "55", any weldor of normal skill can do a better job.

Get trouble-free welds between cast iron and ferrous or non-ferrous metals – with Ni-Rod "55" Electrode, available from most distributors.

You'll see a lot of ways other shops have pared costs in Inco's booklet, "Repair Cast Iron Parts Quickly and Easily". Yours for the asking.

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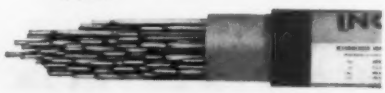

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Editorial

Progress with Welding

The demands American consumers place on products being marketed today are becoming increasingly severe. This searching critical evaluation of industry's wares is brought about not only by increased commercial activity, but by more complex functional requirements to meet modern applications.

As industrial equipment increases in ratings, and is made to operate at higher speeds and temperatures in automated systems, the manufacturer's responsibility and risk becomes greater. Consequently, industry must search for methods and materials which will provide maximum insurance of these aims.

The welding industry provides new methodology and techniques both for improving an existing application and for developing applications previously not possible. The industry, however, must be vigilant in prescribing its relatively new method of joining. The industry can also prove helpful by pursuing new developments in the welding field, and by correlating its needs with vendors, and research and development organizations.

Automation in welding is virtually an untapped market. As industry becomes aware of the precision by which the welding process can be controlled, more sales of highly technical equipment will result. While a precision-operating welding facility will cost more initially, the precision design of the facility's components will reduce production costs.

The welding processes used for joining have become highly technical. To be a front runner in design and shop application, the welding industry must seek out properly trained personnel to organize and to correlate these activities. Educational institutions are in an ideal position to assist the welding industry in developing engineering personnel to apply welding processes to the design and manufacture of our products.

The welding industry must devise and improve economic evaluations of associated productive processes. In so doing, we can obtain optimum economical and functional performance in manufacturing.

Much has still to be accomplished in determining selection, shaping and placement of materials, type of joint and size of weld for correct application. Similarly, much has to be done to develop more accurate information and uniform standards with respect to the behavior of metals and the metallurgical process during the welding operation.

Education and experience are not short cuts to our goal. But with perseverance, as we work on a sound process such as welding, we can look forward with optimism.

A. Edwin Carter
VICE PRESIDENT—MANUFACTURING
WORTHINGTON CORPORATION

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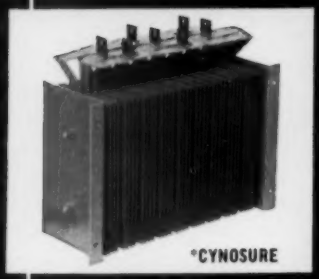

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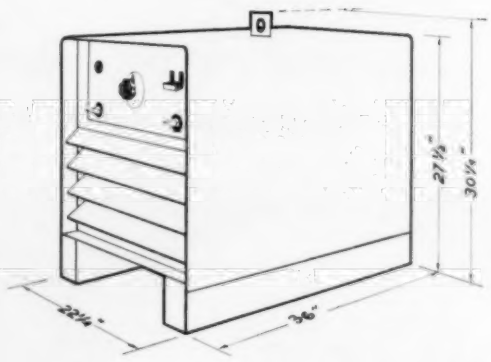

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*CYNOSURE: Anything to which attention is strongly turned; a center of attraction.

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Compressed-air carbon-arc process for metal removal has a wide range of applications in metalworking industries. Because the process does not depend on oxidation, it can be used on ferrous and nonferrous metals alike

Recent Metal-Removal Developments with **Compressed-Air Carbon-Arc Process**

include edge preparation, defect removal, weld-deposit removal and scarfing operations

BY MYRON D. STEPATH, HOMER B. NELSON AND WM. J. COUGHLIN

The compressed-air carbon-arc process, as the name implies, consists of melting the metal to be gouged or cut with an electric arc and blowing away the molten metal with a high-velocity jet of compressed air parallel to the electrode. Because it does not depend on oxidation, it works on metals which do not oxidize as readily as those which do. Equipment used is a special torch which directs a stream of air along the electrode and external to it. The torch is connected to an arc-welding machine and any ordinary compressed-air line, delivering approximately 100 lb per square inch of compressed air. Since this pressure is not critical, normally no regulator is necessary. The electrode used is a special composition of carbon and graphite and is usually copper-clad to increase its life and provide a uniform groove, as well as reduce radiated heat. In most cases, d-c reverse polarity current is used. However, in some instances, as described later on, a-c is also used as well as d-c straight polarity. The current requirements are shown in Table 1. These values are suggested and not mandatory, since job conditions determine actual operating requirements and results.

MYRON D. STEPATH is President, HOMER B. NELSON is Chief Engineer and WM. J. COUGHLIN is Technical Service Manager at Arcair Co., Lancaster, Ohio.

Paper presented at AWS 40th Annual Meeting held in Chicago, Ill., April 6-10, 1959.

Use in Foundries

The most extensive use of compressed-air carbon-arc cutting is in foundries, principally steel foundries where it has, to a large extent, replaced other methods of casting conditioning (see Fig. 1). Although it was first used in steel foundries to remove defects from castings, later it was found an excellent and economical method for washing off excess metal, such as the pads remaining when pouring gates and risers were cut from the castings. At the present

Table 1—Current Requirements

Electrode size, in.	5/32	3/16	1/4	5/16	3/8	1/2	5/8	3/4
Minimum	80	110	150	200	300	400	600	800
Maximum	150	200	350	450	550	800	1000	1400

Fig. 1—Savings from use of the compressed-air carbon-arc process are often large in foundry casting-conditioning operations. One foundry reported an estimated savings of $130,000 to $150,000 a year by using the process for this operation. Castings vary from a few pounds to several tons

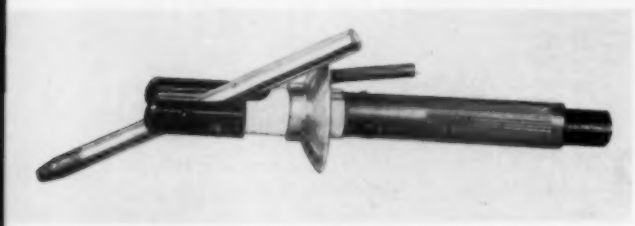


Fig. 2—This torch, with a fixed electrode angle, is used for pad-washing operations

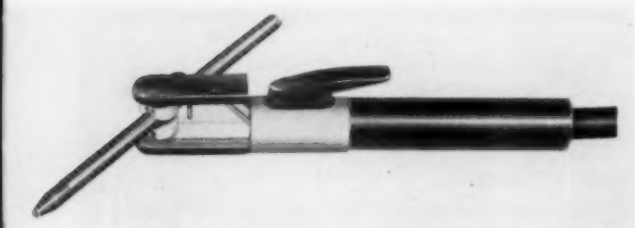


Fig. 3—Special foundry model has an extra head and set of air jets. This permits operator to change direction of travel without stopping to reposition the electrode

time, in many foundries, it replaces swing grinders and chipping for this purpose. In Fig. 1, note the size of the leads and the gantry setup for handling them. In this application, 1200 amp are being used, and in some instances 1600 amp have been used with $^3/_4$-in. electrodes. The use of these high currents is probably the most outstanding recent development in the use of this process in the steel foundry. In order to make this possible, it was necessary to design heavier torches especially suitable for this type of service (see Fig. 2). The pad washing torch

Fig. 4—U groove is made by butting plates together and making a single pass with the torch

handles $^3/_4$-in. electrodes at a fixed angle and is the best available for this operation. Smoothness of finished work is often very satisfactory with no need for grinding.

Types of Power Sources

Such work was not possible until suitable power sources were available. Special arc-welding machines have been produced by a number of manufacturers and fall in two principal types: (1) large, single, constant-voltage machines and (2) smaller drooping-curve units capable of being paralleled to produce the required currents. One welding-machine manufacturer has designed a constant-voltage motor generator specifically for this process and it has proved itself through several years of service. Another manufacturer of rectifiers has developed a system for paralleling them to give sources of current in 600 amp multiples.

Increased use in casting conditioning, especially fin removal in the internal areas of complicated castings such as freight car frames, led to the requirement for a more versatile torch for foundry operations. This torch, shown in Fig. 3, has two rotating heads; one on the top and the other on the bottom of the electrode, so that it may be operated in any direction or from one direction to another without changing the position of the electrode as is necessary in single-head torches. It can also be used for pad washing, though it is not quite as efficient for this particular purpose as the fixed-angle torch in Fig. 2.

Development of Special Electrodes

When the compressed-air carbon-arc process was first developed, it could be operated on d-c reverse polarity only. However, a little over a year ago, after three years of research, an a-c electrode was

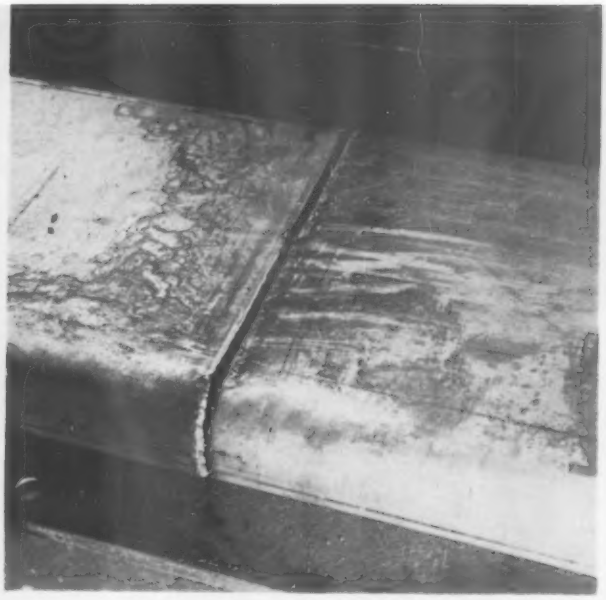


Fig. 5—The groove resulting from the operation in Fig. 4 is ready for welding, no cleanup required. Additional savings are realized because two plate edges are prepared in one operation

introduced. This electrode found application in plants which did not have dc and also in cast-iron foundries where performance was found to be much better than that of the d-c electrode. The normal d-c reverse-polarity electrode when used on cast iron produces a tenacious slag which restricts the gouging or cutting operation and slows down the process. It can be used, but it is a little slow. The a-c electrode, on the other hand, through a series of minute explosions blows this slag off the groove so that a cleaner groove and a more rapid speed is possible. This electrode can also be used on d-c straight polarity. Since the advent of this new electrode, the process has been accepted by the malleable-iron foundries and also by the ductile-iron foundries where the removing of gates and risers is often quite a problem. Previously, these gates were broken off with sledge hammers; however, with ductile iron it is not possible to break off these gates and risers by such blows, and the compressed-air carbon-arc process has been found to be very effective in removing them.

Fabrication Industries

The second large application of this compressed-air carbon-arc process is found in metal fabrication. In fact, this is the field in which the process was originally developed. It was first used to remove stainless-steel welds from naval armor; then, to take out welding defects, to clean out the roots of welds, and to widen grooves that have pulled together. Usage for such purposes is still quite common. In many plants the process is being used for one particular application and not in use on others where it would also have made savings possible. A typical example is the removal of lifting pads and erection clips.

In addition to the uses previously described, many plants are now preparing plates for welding by butting them tightly together and then running the gouging torch down the joint. The resulting U groove, from a design standpoint, is quite preferable to the V groove. U grooves have not been used extensively in the past because of the expense involved in achieving this contour. Table 2 shows the saving in weld metal by using U grooves instead of V grooves. Considering that weld metal costs several dollars per pound to deposit, the economy obtained by joint design alone can readily be seen. With the compressed-air carbon-arc process, it is possible to produce a U groove on both sides of the joint simultaneously and it is cheaper than producing a V groove by ordinary means. The customary procedure is to butt the plates together with square edges and to run the torch down the joint, thereby beveling both edges. After this side is welded, the plates are reversed. A U groove is gouged to sound metal on the reverse side which is then welded, producing a full-penetration weld much more economically than a V groove or by separate beveling. This method also saves much fitting time, as well as time spent in moving the work.

The Pacific Car & Foundry Co. in Seattle, uses the technique just described to prepare certain joints manually. This is illustrated in Figs. 4 and 5. Figure 4 first shows the plates square-butted together, with the operator grooving the joint; Fig. 5 shows finished manual gouge. This particular application points out the advantage of using the arc-gouging method in a joint containing a curve, since the latter normally presents a problem in

Table 2—Comparison of Weld-Metal Volume Required in V and U Joints per Inch of Joint[a]

Material thickness, in.	Joint type	Area, sq in.	Weight of weld metal, lb
1/2	Single V	0.294	0.0833
1/2	Single U	0.243	0.0687
5/8	Single V	0.400	0.1132
5/8	Single U	0.317	0.0898
3/4	Single V	0.525	0.1485
3/4	Single U	0.395	0.1118
7/8	Single V	0.666	0.1885
7/8	Single U	0.480	0.1360
1	Single V	0.827	0.2340
1	Single U	0.571	0.1640
1 1/4	Single V	1.191	0.3370
1 1/4	Single U	0.768	0.2175
1 1/2	Single V	1.648	0.4660
1 1/2	Single U	0.986	0.2790
1	Double V	0.539	0.1528
1	Double U	0.522	0.1475
1 1/8	Double V	0.752	0.2126
1 1/4	Double U	0.652	0.1845
1 1/2	Double V	1.000	0.2830
1 1/2	Double U	0.816	0.2310
1 3/4	Double V	1.284	0.3630
1 3/4	Double U	0.990	0.2800

[a] This table was taken from a paper given at the Canadian Welding Seminar by H. Thomasson and S. Kerr of the Canadian Westinghouse Co., Ltd. Courtesy of *Canadian Metalworking* magazine.

Fig. 6—Tank fabricators use technique shown in Figs. 4 and 5 to eliminate prebeveling operations. This work can also be performed with an automated torch

Fig. 7—The resulting groove in this picture is uniform and of good quality. With manual operation the results are dependent on operator skill

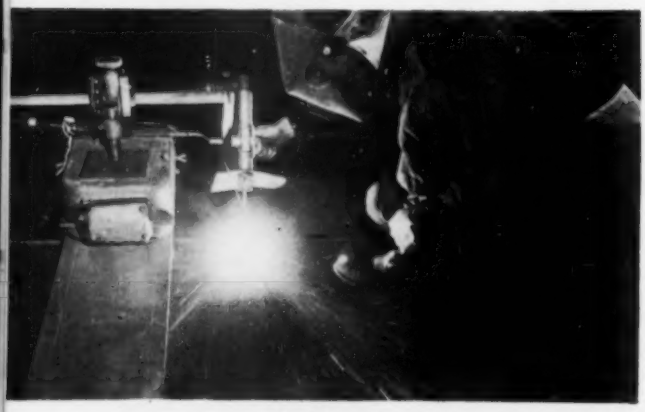


Fig. 8—Operations in heavy-plate fabricating shops use semiautomatic equipment to prepare work for welding

prebeveling. In this case, the groove was previously formed by chipping and the operation required 2 hr; it was done in 5 min with a compressed-air carbon-arc torch—a saving of 90%.

Figure 6 shows a typical manual application of the process in tank work by such companies as American Steel's Leader Division, Decatur, Ill.

In manual work, the quality of the groove produced is entirely dependent on the skill of the operator. In the Kaiser Steel Corp. plant in Los Angeles, the torch is mounted on a tractor for use in bridge fabrication (see Fig. 7). In this picture, $^1/_2$-in. diam electrodes are used and racked by hand as consumed to produce the groove shown. Note the contour of the groove which is well suited for automatic welding, and the automatic-travel torch designed for this special application.

The "L" model torch in Fig. 8 fits into a normal cutting-torch bracket. As can be seen, it provides a means for readily bringing the torch closer to or away from the plate, and enables the operator to produce much more uniform grooves than could be produced by hand operation. This torch has also been set up in a jig on rotating fixtures to provide grooves in tanks or clean out the roots of welds in tank circumferential seams.

The fully automatic head shown in Fig. 9 makes it possible to work at speeds as high as 82 ipm. It can operate from a tractor or can be set up in a welding fixture.

Applications in Plant Maintenance

Perhaps the broadest use for the compressed-air carbon-arc process has been in maintenance. Since

it provides an efficient tool for veeing out a crack for repair by welding, for washing off hard-surfacing metal, or for cutting many of the metals which cannot be cut by the oxygen process, its versatility makes it a very important maintenance tool. In this field, the small-size manual torches have not been supplanted. Although the standard-model general-purpose torch (see Fig. 10) which takes up to a maximum of $^{3}/_{8}$-in. diam electrodes is used most commonly, a smaller torch which consumes less compressed air is also available. The size of the air orifice in this torch has been reduced to the minimum practical size for use with the $^{1}/_{4}$-in. or smaller diameter electrode. This means that the amount of air required is low enough so that a shop with a small compressor can make use of the process. Where no compressor at all is available and bottled air is to be used, the extremely low volume required is also an asset. With this torch, it is possible to operate on pressures as low as 40 lb.

As mentioned previously, the recent development of the a-c electrode has broadened the scope of use on cast iron. This electrode is also advantageous on other materials. Recent tests have shown that d-c straight polarity is preferable on some applications with this new electrode.

The repair of the 5000-lb ram-type hammer shown in Fig. 11 gives an indication of how the process is being used in maintenance. This hammer was cracked and it was necessary to make a groove in it $37^{1}/_{2}$ in. long by 8 in. deep, and 2 in. wide at the top. Chipping such a groove would take two or three man-days; however, using the compressed-air carbon-arc process, it was done in $2^{1}/_{2}$ hr with $^{3}/_{8}$-in. electrodes, at a cost of $8.62.

The compressed-air carbon-arc process is used extensively by railroads in maintenance operations and to clear wreckage from right of way. Its applicability to any metal and its low-heat-input requirements make it a valuable emergency tool.

Fig. 9—This automatic torch is designed to produce uniform gouging at high rates of speed

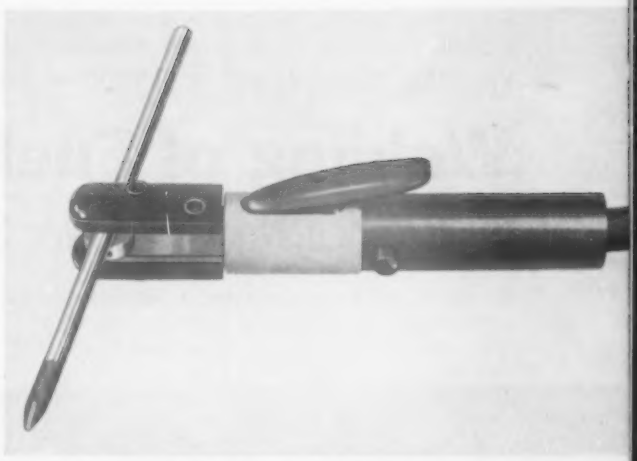


Fig. 10—This manual torch is usually considered an all-purpose tool

Fig. 11—Repair of this 5000 lb ram-type steel-mill hammer was accomplished by the compressed-air carbon-arc process, in a fraction of the time usually required by other means

Processes, materials and quality-control methods are described for the

Welding of Fuels and Controls

for Dresden Nuclear Power Station

BY C. N. SPALARIS AND J. W. WEYERS

Welding of fuel-end closure in the inert-atmosphere chamber

SYNOPSIS. In this paper, the processes, materials and quality-control methods are described for fabricating Zircaloy-2 clad, uranium dioxide containing fuel elements and boron-bearing stainless-steel control rods. Certain unique techniques were required in handling Zircaloy-2 in order to preserve its satisfactory corrosion resistance and favorable mechanical properties. Certain developmental aspects of end-closure welding are described.

Welding of boron-bearing stainless-steel control rods required special weld-junction geometries and techniques to overcome material brittleness and distortion.

Fuel Elements

Introduction

The fuel elements for Dresden Nuclear Power Station[1] consist of uranium-dioxide cylinders, or pellets enclosed into Zircaloy-2 tubular segments $^1/_2$ in. in diam and 27 in. long. These are assembled into bundles, approximately 5 in. square and 10 ft long. It takes 144 segments assembled into four layers, each containing 36 segments, to make up a complete fuel bundle. There are 480 bundles in a complete core for the Dresden Station. Each bundle is surrounded with a square Zircaloy-2 channel or shroud.

Segments containing the uranium-dioxide pellets are capped by welding Zircaloy-2 plugs on each end. This is accomplished in an inert atmosphere using the nonconsumable electrode (or tungsten-arc) welding technique. Because welding of the end closures require a transition through the molten phase, all traces of reactive gases must be excluded from the weld area. Traces of nitrogen, hydrogen and oxygen, when combined with the zirconium, have deleterious effect on the corrosion resistance and mechanical properties of the alloy. Acceptable welds have been achieved in controlled-atmosphere chambers and in large production quantities, with a high acceptance yield. The inspection techniques and standards used are such that only segments of the highest integrity are accepted because fuel reliability is an important factor in achieving economic power production.

Materials

Both seamless and weld-drawn tubing have been welded successfully, using the same process. End plugs are either machined from a large-diameter bar stock or hot forged from a small-diameter bar stock. The latter method results in substantial savings in material and machining, but it is restricted to end plugs of simple design.

All materials originate from magnesium- or sodium-reduced zirconium sponge (Kroll process) which is subsequently alloyed in vacuum-melted ingots. A description for fabrication of seamless tubing was presented elsewhere.[2] The weld-drawn tubing was fabricated from fully annealed strip produced from vacuum-melted ingots by first shaping into tubing, then welding the seam using an inert-atmosphere jig. Subsequent to welding, the tubing was mandrel drawn, then worked by sinking to approximately 25% total area reduction. Typical chemical analysis for the Zircaloy-2 components is given in Table 1.

C. N. SPALARIS and J. W. WEYERS are engineers at the Atomic Power Equipment Department, General Electric Co., San Jose, Calif.

Table 1—Typical Chemical Analysis of Zircaloy-2

(Ppm) except as noted

Cu	Su	Ni	Al	Mn	Si	Cr	Fe	Mg	N	H
35	1.5%	0.058%	43	49	74	0.099%	0.13%	10	50	30

Of the elements in Table 1, copper, aluminum, nitrogen and hydrogen are critical to the corrosion resistance of Zircaloy-2 in high-temperature high, pressure water or steam. One of the most important tests for acceptance of incoming material is the corrosion test. It is specified that the maximum weight gain, in an autoclave operated at 750° F and 1500 psi steam for a 14-day period, be less than 38 mg/dm.^{2} Excessive weight gain and grey or white discoloration of the tested coupons is cause for rejecting the lot from which samples are taken. Typical corrosion-test results are shown in Fig. 1 for both seamless and weld-drawn tubing. Tubing is hydrostatically checked at 3800 psi for strength, and helium-leak tested for possible microcracks through the wall. The tube dimensions are 0.500 in./0.505 in. ID, 0.033 in. wall thickness and straightness is 8 mils per ft.

Reduction in area by cold work is limited to 25% for the seamless tubing, but 35% minimum is required for the weld-drawn tubing subsequent to welding. This latter requirement is needed to homogenize the grain structure throughout the wall thickness and periphery. In both seamless and welded tubing, small average-size grains are desirable because of potentially higher ductility but no specific requirement is imposed for the incoming material.

The Welding Process

It is imperative that surfaces to be welded are clean, free of dust, dirt, grease or oxides. Tubing is washed in detergent, then rinsed in hot water, dried and finally vapor degreased. Each tube end is then etched in hydrofluoric-nitric solution (HF 3.5%, HNO_3 36% by weight), followed by rinsing and drying. End plugs are cleaned in a similar manner, but they are not etched. Following cleaning, the sequence of fabrication is as follows:

(*a*) Pressing the first end plug into tube.
(*b*) Welding first end plug.
(*c*) Loading segment with uranium-dioxide pellets.
(*d*) Filling tubes with helium and pressing the second end plug.
(*e*) Welding of the second end plug.

A tight fit is required at the weld junction to prevent blow-holes and peel-back. After loading with pellets, the second end plug junction must be free of uranium-dioxide dust, otherwise excessive undercutting and porosity will result at the weld face.

The first end plug weld is deposited in an argon atmosphere, using a $^1/_{16}$-in. diam, 2% thoriated-tungsten electrode and 76 to 78 amp of welding current. High-frequency start and crater-elimination steps are also used. The electrode remains stationary and the segment is rotated at about 14 to 15 ipm; a single-pass weld with the crater-elimination sequence takes a total of 8 sec.

The electrode tip is held at 30 to 40 mils from the weld joint, slightly offset, toward the end plug. Straight polarity (electrode negative) is used. Copper chill blocks having the appropriate geometry were used to remove heat from the weld zone and thus reduce distortion resulting from intense localized heating. In addition, chill blocks help reduce the slight amount of discoloration usually found at the heat-affected zones.

The second end closure is made in a helium atmosphere, because of the desirability of having good heat transfer characteristics at the gap between uranium dioxide and fuel-element jacket. In addition, helium provides an easy and reliable leak-detection monitor, using a mass spectrometer. Welding parameters in helium are identical to those used for the first weld-end closure, except that the welding current is 48–52 amp, the speed of rotation is 24 ipm and the time required for a one pass weld is 5 sec. To achieve pure atmosphere inside the welding chambers, they are first evacuated to a pressure of about 0.3 microns of mercury and then back-filled with helium or argon gas. The back-filling time is held to a minimum, thus reducing contamination from microscopic leaks when the system is isolated from the vacuum pump. The pressure inside the chamber is kept constant at all times during welding, using an oil equalization valve. Lots of 100 to 150 segments can be processed before changing the chamber atmosphere depending on the leak rate of the welding chamber, the purity of gas and the cleanliness of the segment surfaces to be welded. The entire operation of pumping down and back-filling the chambers takes less than one hour for a system having a total volume of 90 cu ft.

Acceptance Tests

1. *Dimensional.* Because of the close tube-to-tube proximity in the assemblies, the 27-in. segments

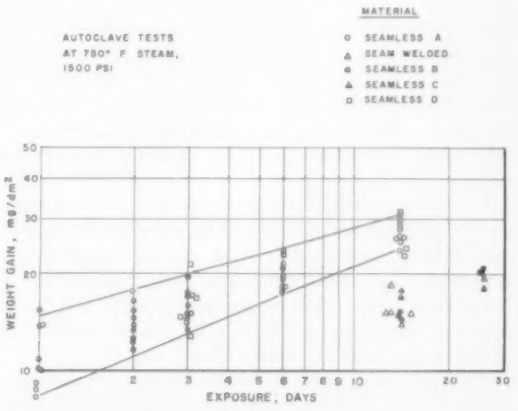


Fig. 1—Typical autoclave corrosion-test results for both seamless and weld-drawn tubing

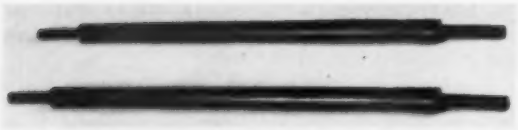


Fig. 2—Tensile-test results for seamless-tubing welds. Tested at room temperature, the load at fracture was 3760 lb with 10% elongation, specimens 9 in. long. Fractures occurred away from the heat-affected zones

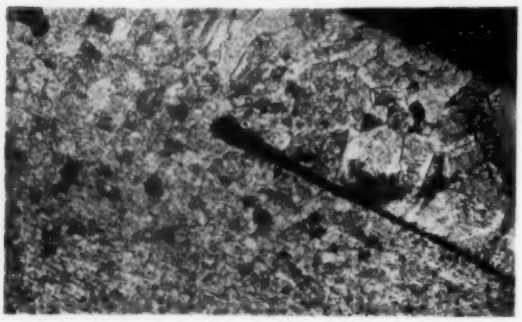


Fig. 3—Typical weld area, polarized light. X 50. (Reduced by 1/3 upon reproduction)

must have an over-all bow of not more than 20 mils. The axis of the tubing and end plugs must be such as to produce the required straightness to avoid a possible contact between two adjacent segments during reactor operation. It is for this reason that the welding variables were carefully selected. Judicious choice of chill blocks eliminated practically all distortion at the end plugs where very close tolerances must be maintained. The majority of segments have an over-all bow not exceeding 12 mils.

2. *Leak Tightness.* This is measured with a helium mass spectrometer using a sensitivity capable of detecting leaks with a rate of 10^{-8} cm^3/sec. Although very few leaks have been detected so far, it is felt that this test provides an inexpensive insurance for fuel integrity. Segments are tested in groups of 3, unless a leaker is detected. The total test time required for each group is less than 30 sec. The testing is carried out in chambers equipped with electronically controlled valves that are actuated when the pressure in the test chamber reaches a preset value. The valve to the mass spectrometer opens only when the pressure in the chamber reaches 0.1 micron of mercury.

3. *Radiographic Tests of the Welds.* These tests are complimentary to the helium mass spectrometer test. Using an exposure of 45 ma min, appropriate correction blocks and fine-grain films, a sensitivity of 2% is achieved. This means that defects of 10 mils in diam can be detected faintly, as it is determined by standard for each exposure.

Metallographic tests have shown that the selected radiographic standards, even allowing 10 mil defects, are satisfactory. Hydrostatic tests indicated that welds with undercutting defects not exceeding 15 mils in effective diameter fail at 95% of the pressure of those that are free from undercutting. The majority of the welds tested, however, do not fail at all, but the tubing base metal ruptures first. This is to be expected since the tensile and yield strengths of the weld composed primarily from transformed beta grains is higher than the base metal, having equiaxial alpha structure.[3] Tensile tests of typical segments are shown in Fig. 2, and typical weld areas in Figs. 3 and 4.

4. *Autoclave Tests.* The purpose of this test is to ascertain whether or not a given fuel segment has objectionable surface defects that will cause a rapid rate of corrosion of the cladding. To accomplish this, the segments are given a rigorous test at 750° F, 1400 psi pressure for a period of 72 hr. Acceptable segments are covered with a uniform black, lustrous, hard-oxide coating, indicative of normal corrosion behavior of Zircaloy-2. Any spots, streaks or "clouds" having grey, white or brown color are suspect for objectionable surface contamination. Based on controlled experiments, segments with certain minor defects have been irradiated in VBWR to study the progress of the corrosion on these spots. The results will help establish realistic standards of acceptance for autoclaved segments. Meanwhile, all defects are carefully scrutinized and marginal segments are reprocessed. Cleaning of the segments prior to the autoclave testing is very important and critical. Cleaning involves etching of the segments in $HF\text{-}HNO_3$ solution followed by rinsing. Segments failing to pass the autoclave test the first time can be reprocessed by removing the oxide and recleaning. If they fail the second time, they must be scrapped, since any further reprocessing results in reducing the wall thickness to an undesirable degree. The number of welds that failed to pass the autoclave test thus far is very small.

5. *Weld Reprocessing.* Welds containing defects revealed from the radiographic inspection can be salvaged by multipass welding. Four or five passes are usually sufficient to reclaim the large majority of all rejected welds. Blowholes and undercutting are the most frequent defects encountered. Systematic studies revealed that both types of defects result from overpressure of helium gas entrapped between end plug and tubing interface. Trapped helium has no room to escape during the welding cycle, except through the molten pool of metal, causing either a blowhole or severe undercutting, depending on the severity of the gas entrapment. The mechanism of blowhole formation and the metallographic specimen of a typical weld undercutting is shown in Fig. 5. The end-plug design was adjusted to minimize this adverse condition; in addition, chill blocks were used to carry the heat away from the weld joint as rapidly as possible.

Irradiation Experience

Several assemblies, using identical processing methods as those used for DNPS, were fabricated and irradiated in VBWR. Although the accumulated

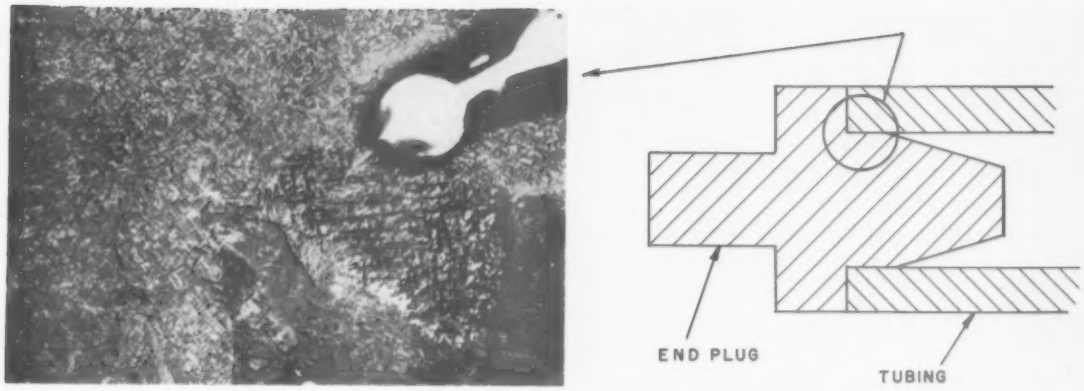


Fig. 4—Typical weld area viewed under polarized light. X 250. (Reduced by 1/3 upon reproduction)

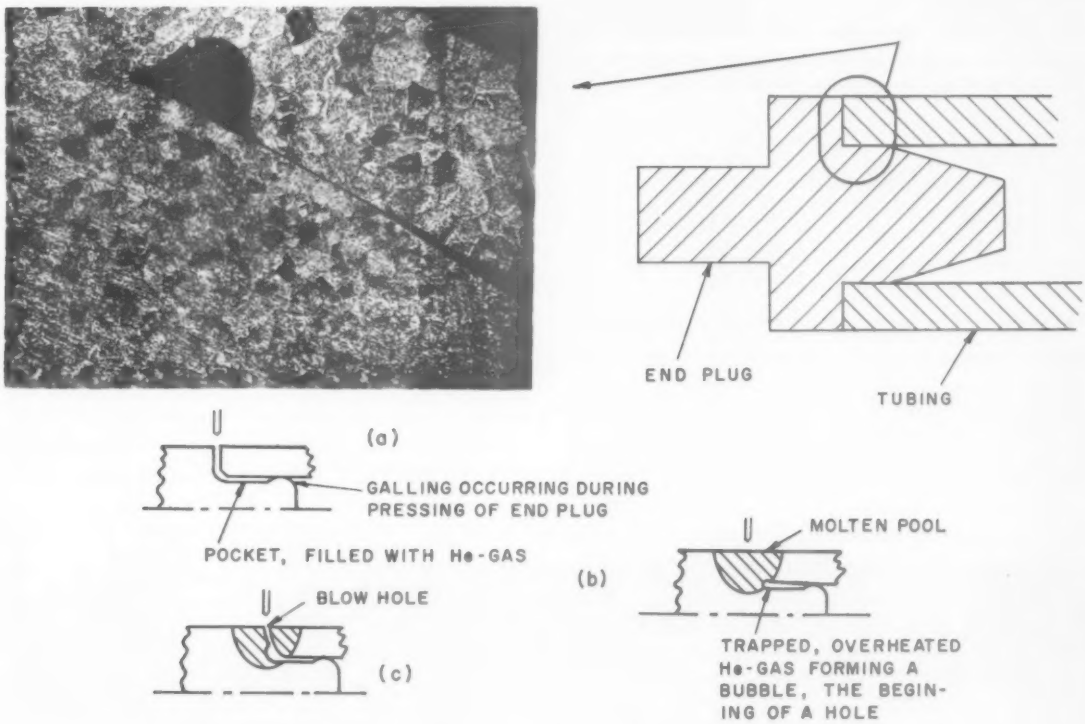


Fig. 5—Mechanism for undercut formation. Photomicrograph shows actual undercut revealed by radiography

exposures are still modest, the heat-flux rates are much higher than those contemplated for the Dresden Station. Periodic post-irradiation examination revealed that no distortion, excessive corrosion or any other measurable defect occurred from reactor exposures in excess of 2500 MWD/T. Areas of marginal autoclave acceptance remained unchanged, and all welds have shown no defects.

Control Rods

Introduction

The Dresden core required 88 control-rod cruciform geometric cross sections 10 ft long with a 4-in. web, containing a neutron blackness equivalent to 2% natural boron in 3/8-in. thick, 18-12 stainless steel. These cruciform sections are subjected, in

service, to 600° F flowing steam and water at 1000 psi pressure, impact, wear, shock loads and neutron bombardment.

The design basis was established, preliminary irradiation tests on material were conducted, and process development programs on forming and welding methods were completed on full-size prototypes.

Design Basis

The neutron blackness requirements and cruciform shape noted above were established by physics experiments conducted in a critical assembly facility. Fabrication development and irradiation testing at Argonne Laboratories for the EBWR reactor,[4] indicated that 2% boron in 18-12 stainless steel would be a suitable material for a 3-year life.

Material

The chemical composition for the material which was found most suitable is shown in Table 2, and physical properties are listed in Table 3.

The irradiation tests on the material show slight distortion and loss in ductility over extended (10^{21} NVT) periods of neutron bombardment.[5]

Severe material cracking during forging and subsequent rolling resulted if the nickel content was not kept over 12%. Carbon content originally was specified as less than 0.02%. However, the boron-compound additive available contained enough carbon to raise the carbon content of the entire melt to 0.05%. It was found, from impact testing, that 0.05% carbon was acceptable.

Material processing consisted of vacuum melting 2000# ingots, then forging at 1900° F into slabs, finally hot and cold rolling to the thickness required. Annealing was done by heating to 1950° F and then air cooling.

Table 2—Chemical Composition (Percent)

Carbon	0.05 max
Manganese	2.00 max
Phosphorus	0.035 max
Sulfur	0.030 max
Silicon	1.00 max
Chromium	18.00 to 20.00
Nickel	12.00 to 14.00
Boron	2.00% ± 0.15%
Iron	Balance

Table 3—Physical Properties Requirements (@ 70 ± 5° F)

Tensile strength, minimum, psi	70,000
Yield strength, minimum, psi	40,000
Elongation in 2 in., minimum, percent	5
Charpy impact strength, minimum, ft-lb	6

Fabrication Development—Formed-angle Rods

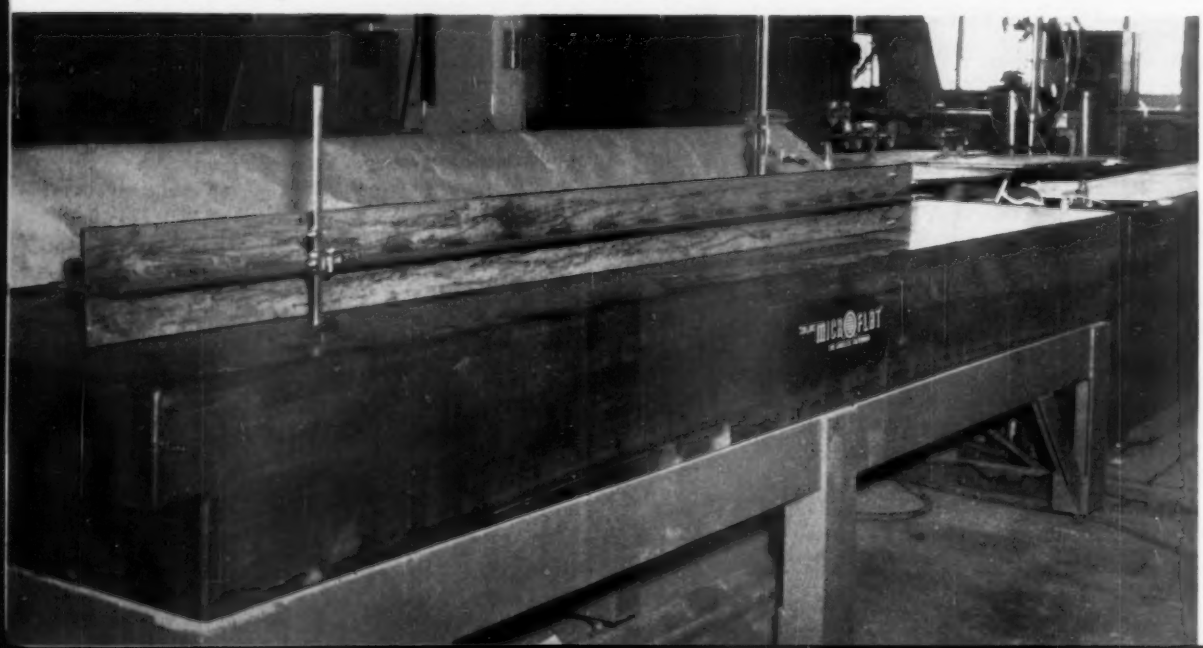
Preliminary bend tests were made at room temperature after various annealing operations, and also at various elevated temperatures. The bend tests indicated that, to successfully bend $^{3}/_{16}$-in. material to a $^{3}/_{8}$-in. radius, bending must be done above 1600° F. The full-size sheets were then heated to 1900° F and bent on the forming press. Optimum resistance welding-machine settings were established on samples, the bent sheets were sand blasted, pickled and resistance welded into the cruciform shape.

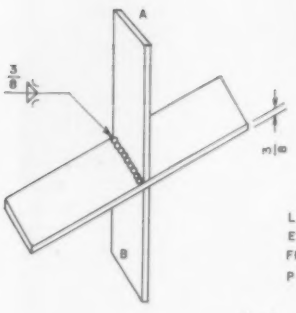
Fabrication Development—Fusion Welding

Since a fusion-welded cruciform rod appeared to offer advantages over the formed-angle cruciform rod, development of a welded control rod was pursued.

Preliminary weld tests were made to determine the optimum joint design. Strength analysis indicated that a solid full-length fillet weld was not required, but an intermittent fillet weld 2.5 in. long on 6-in. centers was adequate. To minimize distortion, all welds were in the same plane around the cruciform. A sharp double chamfer on the "T" member was at first attempted, so that a 100% penetration weld

Fig. 6—Formed-angle intermittent-fillet-welded tee-joint control-rod cruciform





SPECIMEN NO.	FT. LBS. TO FAILURE
1A	28
1B	35
2A	31.5
2B	28
3A	31.5
3B	28

LOAD APPLIED AT EXTREME ENDS OF A AND B OR 3.25" FROM STRESS CONCENTRATION POINT IN CENTER OF SPECIMEN.

(a)

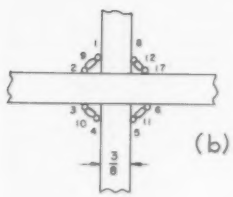


Fig. 7—(a) Impact-test results. (b) Weld-joint design and weld-pass sequence

Fig. 8—Cross section of three-pass fillet weld in 2% boron steel, $^3/_8$-in. thick. X 3

could be obtained. This joint was not successful due to cracking in the base metal adjacent to the weld. E312-16 welding electrode was used throughout the entire weld joint. To correct the base-metal cracking tendency, it was necessary to place a layer weld "butter pass" on each leg of the fillet and then bridge the two layer weld passes with a third weld.

The "butter-pass" technique was deemed more satisfactory than a single-pass fillet weld because of less dilution of the base metal into the weld, and less stress on the base metal-weld metal fusion line.

Figure 7*b* shows the weld-joint design and the weld-pass sequence.

Test Results

Impact-test results are shown in Fig. 7*a*.

In addition, Charpy standard impact tests on the base metal resulted in an average impact value of 7 ft-lb, and a minimum value of 6 ft-lb.

Dimensional inspection analysis showed that the drawing tolerances were maintained as follows:

Max bow in 10 ft—$^1/_{16}$ in.

Max twist in 10 ft—$^1/_{16}$ in.

Max angularity between blades—$\pm\,^1/_4$ degree

Extensive metallographic examination of the welds was conducted to insure that detrimental underbead defects were absent. Figure 8 depicts a ×3 magnification of a cross section of the 12-pass weld.

The fuel-rod assembly is shown in Fig. 9, and the fusion-welded control rod is shown in Fig. 6.

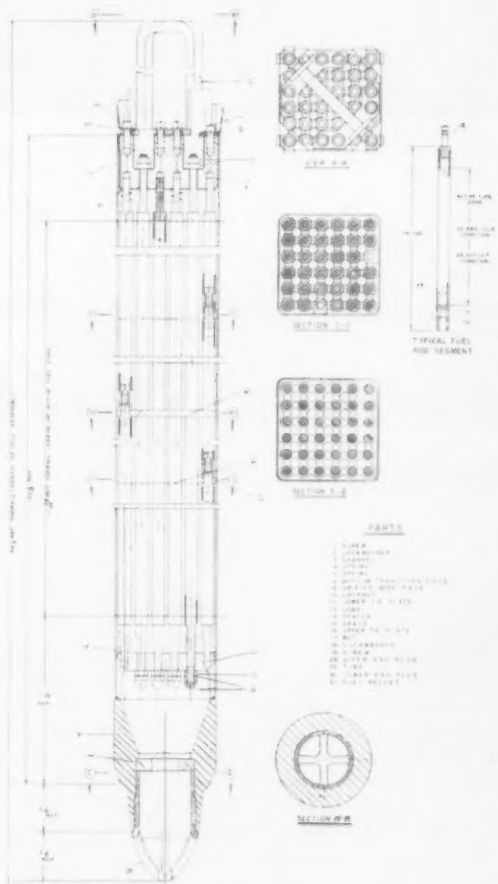


Fig. 9—Fuel-rod and assembly

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2. The Shippingport Pressurized Water Reactor, Page 153, Adison-Wesley Publishing Co., Inc., Reading, Mass., 1958.

3. Simcoe, C. R., "Mechanical Properties of Welded Zirconium," WAPD RM 44, May 1, 1951.

4. EBWR, ANL 5607.

5. Personal Communicaton, N. Balai, Argonne National Laboratory.

Fig. 1—Circumferential joint in stainless-steel-clad pipe being welded in laboratory. Sealing weld is made with gas-shielded tungsten-arc torch. Plastic ends on pipe sections permit viewing inside surface plus inert-gas shielding during welding

Results of test program indicate that, under production conditions normally existing in a field welding project, predictable and satisfactory joints can be made in

Welded **Clad Steel Pipe** for Reactor Construction

BY WILLIAM H. FUNK

New welding procedures to insure the strength and corrosion resistance of welded stainless-clad steel pipe for nuclear reactors were tested at Lukens Steel Co. recently. The results indicate that under production conditions normally existing in a field-welding project, predictable and satisfactory weld joints may be made on clad steel pipe. Both the strength and corrosion-resistance characteristics required can be obtained without the need for unusual, hence more costly, quality-control procedures.

These same procedures are applicable, and for the same reasons, to Inconel-clad pipe for use in those reactor systems where a high degree of resistance to stress corrosion is required.

WILLIAM H. FUNK is associated with the Lukens Steel Co., Coatesville, Pa.

Background

Stainless-steel-clad pipe is manufactured from stainless-steel-clad plate, which consists of a layer of

solid stainless steel integrally and permanently bonded under heat and pressure to a layer of carbon or alloy backing steel.

Interest in clad-steel pipe for reactor construction derives from its ability to offer the required properties for the service conditions at a substantially lower cost. This lower cost can be further described to include reduced space requirements for over-all reactor-piping systems (obtainable because clad pipe can be used with a thinner wall and this pipe has lower thermal-expansion characteristics—therefore reducing the expansion-joint requirements) and actual first-cost expenditures (because of lower material cost and comparative ease of fabricating carbon or alloy steel versus stainless steel or other high-alloy materials).

Stainless-steel-clad plates have been specified for a variety of nuclear applications since the earliest days of the Manhattan Project. More recent uses include the *Nautilus* and other nuclear submarines, the Shippingport reactor vessel and the Dresden reactor now under construction.

The clad-plate producers, seeking additional applications for their product, have more recently looked at possibilities for stainless-steel-clad pipe. The use of stainless-steel-clad plate for reactor-pipe systems is gaining more consideration through the efforts of designers and metallurgists to improve over-all reactor-plant design, as well as the quality standards for material and fabrication, while at the same time obtaining desirable economies in facility costs. An important detail pertaining to quality of fabrication is the circumferential welded joints in the piping system. Our tests were directed toward verification of satisfactory welding procedures.

The Central Problem

In normal welding practice, fabricators avoid depositing carbon steel on stainless steel because under these conditions carbon-steel weld metal tends to become brittle.

But to fabricate lengths of clad pipe in a closed system, where the stainless-steel surface is on the interior and generally inaccessible, welding techniques had to be proved that would necessarily deposit carbon steel on stainless steel but that would nevertheless produce strong, ductile circumferential weld joints.

The techniques tested, and the results obtained, are given in some detail in the discussion and charts that follow.

Basic Procedure

Figure 2 illustrates a suggested method for preparing the pipe ends prior to making the circumferential weld in a pipe joint completely from the outside. (Other methods, differing in detail rather than basic principle, may also be used.)

The seal weld is made by gas-shielded tungsten-arc welding. For best surface conditions on the inside of the pipe, this joint section should be inert-gas backed (argon). A filler rod should not be used when making the seal weld. (However, if it is necessary to use a filler rod to meet some special condition, it should be of the same chemical composition as the cladding material.) Figure 1 shows a laboratory arrangement devised to permit observation of the inside surface as the weld is being made.

Some fabricators may prefer to use an insert strip of the same composition as the cladding material when making this type weld joint. This has been found to be satisfactory. But fit-up, although quite important when an insert ring is not used, is even more important when an insert ring is used.

Above the seal weld, procedure may vary again depending upon the total thickness of the pipe wall

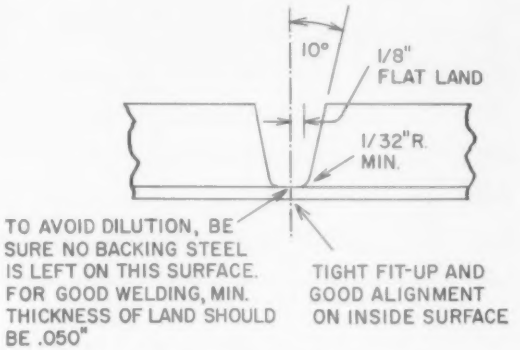
10°
1/8"
FLAT LAND
1/32"R.
MIN.
TO AVOID DILUTION, BE SURE NO BACKING STEEL IS LEFT ON THIS SURFACE. FOR GOOD WELDING, MIN. THICKNESS OF LAND SHOULD BE .050"
TIGHT FIT-UP AND GOOD ALIGNMENT ON INSIDE SURFACE

Fig. 2—Joint detail for welding circumferential seam from outside without a backing strip

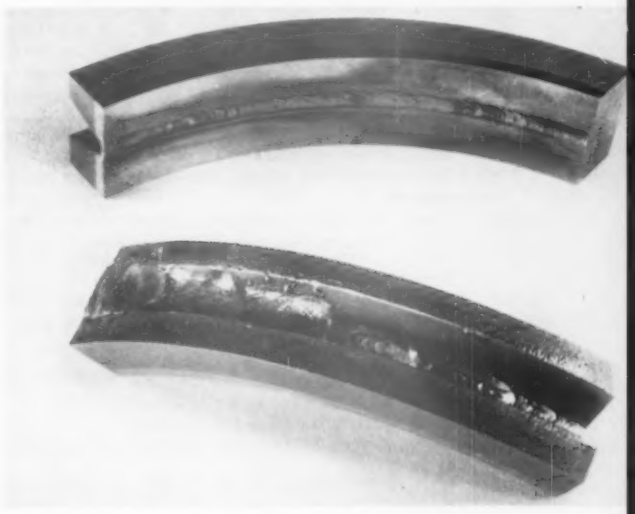

Fig. 3—Section of circumferential weld in stainless-steel-clad pipe. All welding was done from the outside on this section, which has a total thickness of 1 in. with 10% Type 304 stainless cladding on the inside. Weld layers are staggered to show the various steps in the operation. Relatively smooth inside surface is obtained with the aid of inert-gas shielding

Table 1—Welding Procedures

Test No. 1

Pass	
1st	Sealing pass, purged on back side with 15 cfh argon. No filler rod. Welded with 1/16-in. diam thoriated-tungsten electrode with a No. 4 cup tip using 10 cfh argon, 80 amp, d-c straight polarity. Position of specimen—15 deg off vertical. Welded from bottom to top at speed of 1 in. in 45 sec
2nd	3/32-in. diam Type 308ELC-15 electrodes using 65 amp with d-c reverse polarity. Two beads side by side, ground free of ripples, dye-checked. No cracks. Positioned same as for pass No. 1
3rd	3/32-in. diam special Armco-iron, low-hydrogen electrodes using 65 amp with d-c reverse polarity. Two beads side by side, slightly ground. Positioned same as for pass No. 1
4th	5/32-in. diam E7018 electrode using 150 amp, ac. This pass and all remaining passes welded with specimen in flat position
5th	5/32-in. diam E7018 electrode, 165 amp
6th	3/16-in. diam E7018 electrode, 260 amp
7th	5/16-in. diam E7018 electrode, 270 amp
8th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side
9th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side
10th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side
11th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side
12th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side

Table 1—Welding Procedures (continued)

Test No. 2

Pass	
1st	Sealing pass,[a] purged on back side with 15 cfh argon. No filler rod. Welded with 1/16-in. diam thoriated-tungsten electrode with a No. 4 cup tip using 10 cfh argon, 115 amp, d-c straight polarity. Position of specimen—15 deg off vertical. Welded from bottom to top at speed of 1 ipm
2nd	3/32-in. diam Type 308ELC-15 electrodes using 70 amp with d-c reverse polarity. Ground free of ripples, dye-checked. No cracks. Positioned same as for pass No. 1
3rd	3/32-in. diam special Armco-iron, low-hydrogen electrodes using 65 amp with d-c reverse polarity. Two stringer passes side by side, ground lightly. Positioned same as for pass No. 1
4th	5/32-in. diam E7018 electrode using 150 amp, ac. This pass and all remaining passes welded with specimen in flat position
5th	5/32-in. diam E7018 electrode, 165 amp
6th	5/32-in. diam E7018 electrode, 165 amp
7th	5/16-in. diam E7018 electrode, 270 amp
8th	5/16-in. diam E7018 electrode, 270 amp
9th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side
10th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side
11th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side
12th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side

[a] The pass marked in this manner in each test is the one in which a deviation from the standard procedure has been made.

Table 1—Welding Procedures (Continued)

Test No. 3

Pass	
1st	Sealing pass, purged on back side with 15 cfh argon. No filler rod. Welded with 1/16-in. diam thoriated-tungsten electrode with a No. 4 cup tip using 10 cfh argon, 80 amp, d-c straight polarity. Position of specimen—15 deg off vertical. Welded from bottom to top at speed of 1 in. in 45 sec
2nd	3/32-in. diam Type 308ELC-15 electrodes[a] using 65 amp with d-c reverse polarity. Ground out to make thin layer, cleaned free of ripples and dye-penetrant checked. No cracks. Positioned same as for pass No. 1
3rd	3/32-in. diam special Armco-iron, low-hydrogen electrodes using 65 amp wth d-c reverse polarity. Two stringer passes side by side. Positioned same as for pass No. 1
4th	5/32-in. diam E6016 electrode using 140 amp, ac. Started to burn through, electrode too large. This pass and all remaining passes welded with specimen in flat position
5th	5/32-in. diam E6016 electrode, 160 amp
6th	3/16-in. diam E7018 electrode, 260 amp
7th	5/16-in. diam E7018 electrode, 270 amp
8th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side
9th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side
10th	5/16-in. diam E7018 electrodes, 270 amp, two beads side by side
11th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side
12th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side
13th	5/16-in. diam E7018 electrode, 270 amp, two beads side by side

[a] The pass marked in this manner in each test is the one in which a deviation from the standard procedure has been made.

and upon the economics involved. When the pipe wall is less than 3/8 in., or even 1/2 in. in some cases, it may prove economical to complete the weld with high-alloy electrodes (25/12 stainless is commonly used) and to deposit the weld metal manually or by semiautomatic or automatic means.

If high-temperature service conditions indicate that a full alloy weld is not desirable, a transition may be made above a second layer of low-carbon, high-alloy (Type 308L stainless steel) weld metal by using a low-carbon, low-hydrogen type steel electrode. This is commonly called an ingot-iron or Armco-iron electrode. One layer of this transition weld metal should be deposited. To complete the weld, a carbon-steel weld metal matching the physical characteristics of the backing steel may be deposited, by manual or automatic techniques. Figure 3 shows a segment of a pipe welded by this procedure. Each succeeding weld layer was started about one inch further along the joint than the previous weld layer to demonstrate the various steps in the welding sequence.

The Procedure Tested

A series of tests was performed to demonstrate that these special techniques involving transition

Table 1—Welding Procedures (continued)
Test No. 4

Pass	
1st	Sealing pass, purged on back side with 15 cfh argon. No filler rod. Welded with $^1/_{16}$-in. diam thoriated-tungsten electrode with a No. 4 cup tip using 10 cfh argon, 80 amp, d-c straight polarity. Position of specimen—15 deg off vertical. Welded from bottom to top at speed of 1 in. in 45 sec
2nd	$^3/_{32}$-in. diam Type 308ELC-15 electrodes using 65 amp with d-c reverse polarity. Ground free of ripples, dye-penetrant checked. No cracks. Positioned same as for pass No. 1
3rd	$^3/_{32}$-in. diam special Armco-iron, low-hydrogen electrodes[a] using 75 amp with d-c reverse polarity. Two stringer passes side by side. Positioned same as for pass No. 1
4th	$^5/_{32}$-in. diam E7018 electrode using 150 amp, ac. This pass and all remaining passes welded with specimen in flat position
5th	$^5/_{32}$-in. diam E7018 electrode, 165 amp
6th	$^3/_{16}$-in. diam E7018 electrode, 270 amp
7th	$^3/_{16}$-in. diam E7018 electrode, 270 amp
8th	$^3/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side
9th	$^3/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side
10th	$^3/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side
11th	$^3/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side
12th	$^3/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side

[a] The pass marked in this manner in each test is the one in which a deviation from the standard procedure has been made.

Table 1—Welding Procedures (continued)
Test No. 5

Pass	
1st	Sealing pass, purged on back side with 15 cfh argon. No filler rod. Welded with $^1/_{16}$-in. diam thoriated-tungsten electrode with a No. 4 cup tip and 10 cfh argon, 80 amp, d-c straight polarity. Position of specimen—15 deg off vertical. Welded from bottom to top at speed of 1 in. in 45 sec
2nd	$^3/_{32}$-in. diam Type 308ELC-15 electrodes from 65 amp with d-c reverse polarity. Ground free of ripples, dye-penetrant checked. No cracks. Positioned same as for pass No. 1
3rd	$^3/_{32}$-in. diam special Armco-iron, low-hydrogen electrodes[a] from 65 amp. Ground lightly. Positioned same as for pass No. 1
4th	$^5/_{32}$-in. diam E7018 electrode from 150 amp, ac. This pass and all remaining passes welded with specimen in flat position
5th	$^5/_{32}$-in. diam E7018 electrode, 165 amp
6th	$^5/_{32}$-in. diam E7018 electrode, 165 amp
7th	$^3/_{16}$-in. diam E7018 electrode, 270 amp
8th	$^3/_{16}$-in. diam E7018 electrode, 270 amp
9th	$^3/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side
10th	$^3/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side
11th	$^3/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side
12th	$^3/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side

[a] The pass marked in this manner in each test is the one in which a deviation from the standard procedure has been made.

from stainless- to carbon-steel weld metal do not impose excessive costs or hardships on the piping fabricator, such as excessively rigid supervisory requirements or new welding methods and supplies.

The same weld-bevel preparations and the same seal-bead techniques were used in our transition welding procedure as are used in the welding of solid stainless- and even carbon-steel pipe. This is significant because the experience of others[1-2] had shown that these techniques were satisfactorily applicable in production work while deviation into special designs and procedures did not yield good fissure-free results.

The welding procedure followed in this test series is the basic procedure already discussed and is detailed below in Test 1.

In accelerated corrosion tests (Huey test), the corrosion resistance of the stainless-steel surface of the weld proved to be equal to that of the stainless-steel cladding material.

Transverse-tensile tests proved the weld to be as strong as the clad plate itself.

Face, root and side bends demonstrated that the welded joint had adequate ductility. Close microscopic examination showed no evidence of fissures, indicating that the level of hardness of the weld metal and its composition did not detrimentally affect the ductility of the joint.

Deviations Permissible

Even in nuclear-reactor construction, there is always the possibility of inadvertent deviations from the prescribed procedure for edge preparation and welding. To determine whether there was adequate leeway for such deviations from the suggested transition welding procedure, five variations of the Test 1 procedure were investigated.

Test 2 has a deviation consisting of a change in the nose thickness of the edge preparation. Instead of the 0.050-in. thick nose, this one was made $^1/_8$ in. thick. The amperage required for the sealing pass was higher to get full penetration. Other than that, the welding procedure is identical with Test 1.

Test 3 reverted to the 0.050-in. thick welding nose, the deviation here being the manner of deposition of the Type 308 ELC weld metal. A thin layer of this 308 ELC weld metal was deposited purposely to determine the ill effects, if any, of this thinning down.

In Test 4, the standard edge preparation was used and the first two stainless-steel passes were put in as prescribed. In the third pass with ingot iron, a higher amperage was used to determine the ill effects, if any, of additional penetration and dilution caused by this first carbon-steel pass.

In Test 5, the standard edge preparation and procedures were followed until the third pass. In this pass, the ingot-iron weld-metal layer was purposely made thin. The purpose here was to

determine whether dilution or penetration of the regular carbon-steel metal through the ingot-iron weld metal would have a detrimental effect.

In Test 6, the standard edge preparation and welding procedure were followed until the fourth pass was reached. The fourth and fifth passes were deposited with ingot-iron electrodes just as in the third pass. The result caused a much thicker than normal layer of Armco-iron weld metal. This test was made to determine whether this excessive deposit of ingot iron would be detrimental.

The welds in all these tests were made to simulate the difficult conditions which exist when welding a circumferential joint of a pipe system in nuclear service. Thus, when the first three passes were made in the weld joint, the weld coupons were set at an angle of 15 deg off the vertical.

One half of the plate of Test 1 was stress relieved and the other half was tested in the as-welded condition. Investigation of the other specimens was made in the stress-relieved condition.

Face-, root- and side-bend tests were made on the specimens prepared under Test 3. Root bends and side bends were made on the specimens prepared under Test 1, Test 2, Test 4, Test 5 and Test 6.

In all cases, satisfactory bends were made in accordance with requirements in Section IX, Welding Qualifications, ASME Boiler and Pressure Vessel Code.

Transverse sections were cut from each of the specimens and hardness readings were taken at appropriate places in the base metals and in the various types of weld metal. Table 2 shows the results of these Brinell hardness readings. Figure 4 shows sections cut from the welds made in Tests 1, 2 and 3. Note that satisfactory continuity of stainless steel across the weld is obtained in Tests 1 and 2. But in Test 3, dilution is at a level which may be detrimental corrosion-wise.

Transverse-tensile tests were made from each

Table 1—Welding Procedures (concluded)

Test No. 6

Pass	
1st	Sealing pass, purged on back side with 15 cfh argon. No filler rod. Welded with $^1/_{16}$-in. diam thoriated-tungsten electrode with a No. 4 cup tip and 10 cfh argon, 80 amp, d-c straight polarity. Position of specimen—15 deg off vertical. Welded from bottom to top at speed of 1 in. in 45 sec
2nd	$^5/_{32}$-in. diam Type 308ELC-15 electrodes from 65 amp with d-c reverse polarity. Two beads side by side, ground free of ripples, dye-checked. No cracks. Positioned same as for pass No. 1
3rd	$^5/_{32}$-in. diam special Armco-iron, low-hydrogen electrodes from 65 amp with d-c reverse polarity. Two beads side by side. Positioned same as for pass No. 1
4th	$^5/_{32}$-in. diam special Armco-iron, low-hydrogen electrode[a] from 75 amp, ac. Two beads side by side. This pass and all remaining passes welded with specimen in flat position.
5th	$^5/_{32}$-in. diam special Armco-iron, low-hydrogen electrode[a] from 75 amp, ac. Two beads side by side, all ripples ground off
6th	$^5/_{16}$-in. diam E7018 electrode, 270 amp
7th	$^5/_{16}$-in. diam E7018 electrode, 270 amp
8th	$^5/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side
9th	$^5/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side
10th	$^5/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side
11th	$^5/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side
12th	$^5/_{16}$-in. diam E7018 electrode, 270 amp, two beads side by side

[a] The pass marked in this manner in each test is the one in which a deviation from the standard procedure has been made.

Table 2—Brinell-hardness Readings[a]

	Test No. 1 AW	Test No. 1 SR	Test No. 2 SR	Test No. 3 SR	Test No. 4 SR	Test No. 5 SR	Test No. 6 SR
Clad steel (base metal)	153	141	130	141	137	139	139
	139	141	139	130	147	125	140
Clad (weld area)	228	185	205	213	147	172	216
	205	190	190	305	180	190	228
	342	216	305	290	185	228	222
	..	..	..	290	180	176	213
	..	..	..	313	..	..	228
	..	..	..	245	..	..	230
	..	..	..	..	..	..	260
Transition zone	228	260	230	265	255	230	210
	276	322	228	290	255	270	228
	228	297	235	290	260	270	228
	216	216	228	245	255	265	228
	..	..	228	228	265	265	180
	..	..	222	230	190	245	..
	..	..	213	230	180	..	..
	..	..	..	235	195	..	..
	..	..	..	..	190	..	..
Carbon-steel weld	176	162	180	159	159	159	162
	147	147	153	153	147	141	147

[a] Converted from Rockwell hardness tests (A scale).

specimen. Table 3 indicates the results of these tests and the manner and location of the fracture.

Conclusions

This series of tests indicates that normal variations to a specified welding procedure which may occur on a well-supervised project should have no detrimental effect on the quality of the weld made in a stainless-steel-clad pipe.

Test 1 in Table 2 indicates that the stress-relieving treatment slightly reduced the hardness of the base metals and the weld metals. Exceptions to this may be noted in the transition-zone weld metal. This variation can be understood to be dependent upon the specific locations of the hardness readings within this transition zone.

Test 4 in Table 2 shows the very slight detrimental effect of thinning down the Type 308 ELC weld-metal layer. Apparent dilution into the cladding material by the ingot iron has increased the hardness to some slight extent.

Test 5 indicates that excessive heat input and resulting higher dilution of the third pass of ingot-iron weld metal is not detrimental if a sufficiently thick layer of 308 ELC weld metal is present.

The results of the transverse-tensile tests, as indicated in Table 3, show that even an unusually great amount of deposited ingot-iron weld metal does not adversely affect the strength of the weld joint.

Another notation made upon visual observation of the polished cross sections of the weld showed that when the 308 ELC weld metal was not brought up to the bond line, as in Test 3, subsequent dilution effects by the Armco-iron weld metal would probably be detrimental to the corrosion resistance of the stainless-steel surface across the weld joint.

No evident detrimental effects showed up when the welding nose was increased from 0.050 to 1/8 in. As a result of these tests, it would seem advisable to consider the weld-nose thickness of 0.050 in. as a minimum dimension. A nominal design thickness should be 0.060 in., if the cladding thickness and the roundness tolerances obtainable on the specific project will permit going to this heavier nose.

These tests, then, indicate that, under production conditions existing in a field-welding project including clad-steel pipe, predictable and satisfactory weld joints may be made. Both the strength and corrosion-resistance characteristics which are desired and required can be met without the need of unusual quality-control procedures.

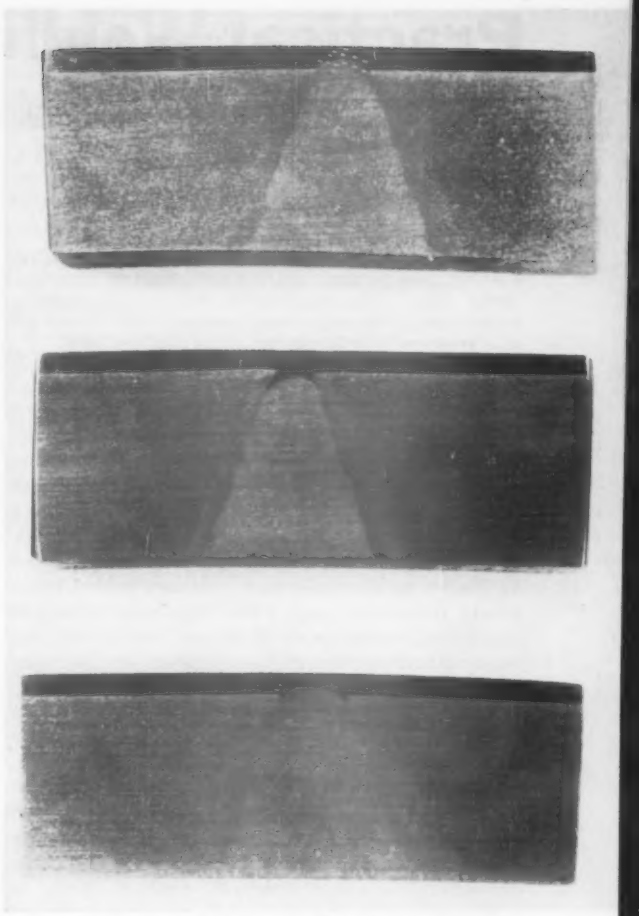

Fig. 4—Cross sections of welds made in Tests 1, 2, and 3 (top to bottom). Indentations caused by hardness testing are seen on top specimen. Cross section at top shows the most desired end result

Table 3—transverse-tensile Tests

Test No.	Yield strength, psi	Tensile strength, psi	Elongation in 2 in., %	Reduction area, %	Remarks
1	56,400	77,000	38	55.0	1/2 cup—broke out of weld
2	55,400	76,700	40	36.3	Angular—broke out of weld
3	54,700	73,600	33	55.1	1/2 cup—broke out of weld
4	57,300	76,900	38	55.9	1/2 cup—broke out of weld
5	53,400	72,700	30	58.0	1/2 cup—broke out of weld
6	59,600	76,800	37	53.9	1/2 cup—broke out of weld

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2. Leonard, W. J., and Thompson, Jr., J. C., "Peripheral Welding of Internally-Clad Steel for Nuclear Reactor Application," *Ibid.*, **36** (3), 243-251 (1957).

Practical Welding Procedures

assist shops to complete fabrication at minimum cost and to meet the end-use demands

BY STANLEY I. ROBERTS AND CLARENCE E. COLE

SYNOPSIS. This is a description of the effort made and methods used to write welding procedures in their most useful form. The need should dictate the minimum instruction for the performance requirement. It explains who prepares, how developed, value and how used.

Introduction

At the 1958 AWS Annual Meeting in St. Louis, it was revealed during one of the panel discussions that a wide variety of practices existed regarding welding procedures. Representatives of different firms reported a widely different approach to this subject. Some used a few words to the welding operator; others more of a technical paper to give instruction for similar welding operation. Some reported that a purely theoretical man wrote elaborate procedures which the production shops did not find to be of any help. Some reported that a procedure was furnished if the production shop so requested. This was not always workable as it was felt that this admitted incompetence, or inability to accomplish the assignment unaided.

Some shops, it was reported, had a procedure issued that was written for some other plant or shop which did not have identical conditions. This left the shop with a choice of attempting to get the procedure changed, or to complete the assignment and let it be assumed the instructions in the procedure were understood and followed. One report, which unfortunately was not an isolated case, stated that the procedures received in one shop were written to impress the reader of the importance of the author, rather than to aid in getting the job done. Usually many words were used to repeat what was common knowledge and too few were used to explain special or new information.

It was pointed out that a simple sketch would be very helpful, especially in sequence instruction. Many of the opinions were to the effect that a picture or sketch conveyed to the user more exactly the wishes of the author and was less often misunderstood.

It is the general consensus that if a procedure is properly authored by a man with knowledge of production-shop needs and of the engineering-performance requirement, then it becomes a beneficial tool for fabrication.

The discussions (and the authors' experiences) indicate that a well prepared procedure should obey basic rules. Some of these are:

1). Be brief as possible.
2). Present instructions pictorially, where possible.
3). Interpret existing rules and codes reliably.
4). Avoid questionable terminology.
5). Translate the codes, specifications, etc., to shop terminology.
6). Avoid reference to any code, specification, instruction that is not readily available and/or usable.
7). Reflect the best thinking of the production personnel, including any allied trades.
8). Be an aid to the production shop.

Purpose

In this paper, the authors will follow the definitions approved by the AWS and the Navy.

Welding Procedure. The detailed methods and practices including joint welding procedure involved in the production of a weldment.

Joint Welding Procedure. The materials, detailed methods and practices employed in the welding of a particular joint.

Welding Sequence. The order of making the welds in a weldment.

The basic purpose, then, of a welding procedure is to aid the production shops in fabricating to a specific performance requirement. The procedure should contain that, and only that, information which the production shop needs. For example it serves no purpose to repeat on each procedure that the opera-

STANLEY I. ROBERTS is a Welding Engineer and CLARENCE E. COLE is a Welding Foreman at the Portsmouth Naval Shipyard, Portsmouth, N. H.

Opinions expressed in this article reflect the views of the writers and do not necessarily indicate the attitude of the Navy Dept. or the Portsmouth Naval Shipyard.

Paper presented at AWS 40th Annual Meeting held in Chicago, Ill., April 6-10, 1959.

Machining the hard surfacing on missile-hangar section

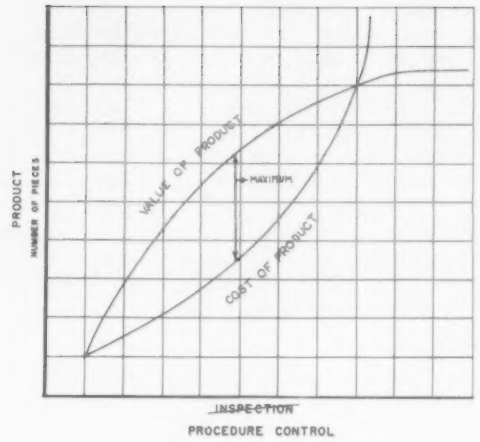


Fig. 1—Procedure control affects the value and cost of the product

1	BASE METAL	TYPE HEAT TREATMENT	CONTROL REQUIREMENT AREA
2	PROCESS	ELECTRIC OTHER	
3	ELECTRODE	TYPE CONDITION	
4	POWER	KIND AMOUNT	
5	QUENCH	PREHEAT MASS	
6	OPERATOR	QUALIFICATION WORKING CONDITIONS	
7	RESTRAINT	MASS SEQUENCE	
8	ALLIED OPERATIONS	MACHINING HEAT TREATING	
9	WEATHER	TEMPERATURE HUMIDITY	
10	QUALITY	INSPECTION METHOD	

Fig. 2—List of some of the variables that may require procedure control

tors must pass a qualification test in Naval shipyards. It is well known that all operators are qualified before being permitted to work on production welding. Unless there is some unusual qualification test, it serves no purpose to repeat the basic qualification requirement in each procedure.

When specifying only the information needed by the shops, the procedure is not a complete historical welding record. It must be supplemented by a report which will state, along with other information, the basic rules, codes or specifications employed by the plant. Of course, this is a good record for repeat jobs within the plant.

The procedure that does give a complete record of what is required is not discussed in this paper as, usually, it is not written for use by the welder or lower echelon of supervision.

Figure 1 shows a cost value chart modified from inspection-quality chart. The vertical distance between the curves represent the optimum in cost-value from inspection. The procedure cost-value works the same way. In other words, as we increase the procedure control, both the cost and the value of the product rise. However, with added control, the value levels off and obviously can reach no higher than a perfect product. Theoretically, the cost can rise to infinity where unrealistic procedure controls prohibit the completion of a single unit.

The optimum from the standpoint of cost and value would be to keep the amount of control to a minimum commensurate with performance requirements of the finished product.

Figure 2 lists some of the variables encountered in the fabrications of weldments. Usually trouble is encountered when we have a combination of several variables reaching the control-requirement area simultaneously. Sometimes some of the variables cannot be changed and it is then necessary to use extra controls on other contributing factors. A practical procedure will control only the minimum number to insure a desired product.

For example, it may be necessary in weather of high humidity to dry the electrodes when welding a fabrication of high restraint, which ordinarily would not be required in the dry season.

Some of the inspection requirements on nuclear or missile work are extremely severe, requiring procedure control on each and every variable. Here again the performance of the product dictates the need.

Figure 2 also explains the often asked question, "This worked before, why not now?" Often it takes a combination of several variables reaching that mythical area of "trouble" to cause the unacceptable product. Some items can be well into the control-area requirements if all the others are favorably in the "low" area.

Preparation

The preparation, then, of a practical procedure is not a simple task. It would be comparatively easy to list controls on all the variables (which too often is done) and let the fabricator worry, or to exercise no controls and let the user beware.

The writer of practical procedures should have experience and training but, more important, he should have the consensus of others involved. The instructions would, then, be the product of many people, not one. To obtain the support of the allied operations, it is necessary that they are in agreement with welders' requirements. The final procedure should be written by staff personnel closely allied with

production management to give it the necessary authority, especially in departments other than the welding department. Usually, this indicates closer contact with the design engineering department and, also, a better knowledge of codes, specifications and the customer's wishes.

The format of the procedure should be in conformance to the need of the fabricator. Its language should be such that the meaning is clear and easily understood. A sketch, either isometric or exploded, should be used where possible to illustrate the product.

Figure 3 shows an isometric view of a missile hangar head and door assembly, and Figure 4 the detail of the hard surfacing required on the head and door. These are only a portion of the entire procedure and indicate the type of format used. The entire procedure on this head and door was interesting because of the close machining tolerances of the hangar and door face. Due to the limiting size of the equipment available to machine the flanges, the hinges were welded after the final machine work, requiring closely controlled procedure. It was written with the close cooperation of the ship-fitting shop, the machine-shop personnel, as well as with the welding shop. Its function was largely to coordinate allied trades as well as to specify a welding procedure.

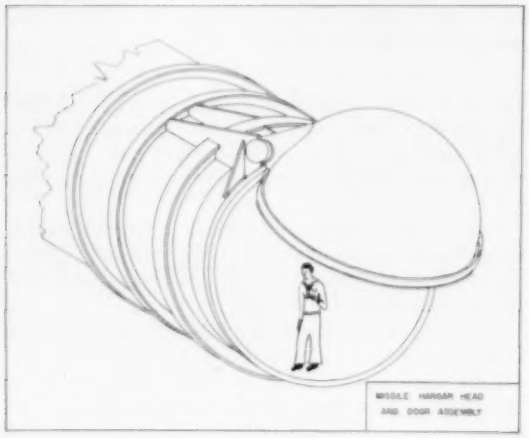


Fig. 3—The hinges were welded after finishing the hard surfacing on the door and missile hangar

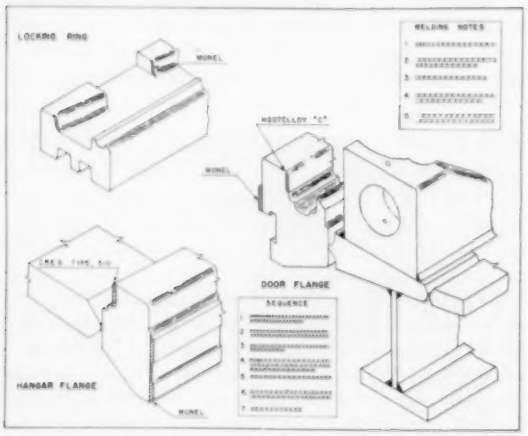


Fig. 4—A page from the procedure which shows hard surfacing on the hanger and door

Figure 5 shows the preparation of a mock-up which is designed to qualify an operator for an individual job and to qualify the procedure. The information is recorded from this and the procedure is written, specifying, among many other things, the exact current and the travel speed. Actually, the operator writes a portion of his own individual procedure on this mock-up. This is an example where nearly all variables are very closely controlled.

Uses

The obvious advantage of the practical procedure is that it assists the shop to complete the fabrication at the minimum of cost and to meet the end-use demands. A correctly written procedure eliminates mistakes by cautioning against them in advance. It aids in the collaboration of all related activities to meet schedules and commitments. It serves to assist intershop communications concerning the routing, scheduling and the general completion of the job. Also, it makes a shop record to use on future similar assignments.

A successful procedure can be used by design engineers to assist in designing for a better product at a lower cost. It will also aid in writing a historical record where one is required. If it is a practical procedure, then it more nearly reflects what was done in the shop.

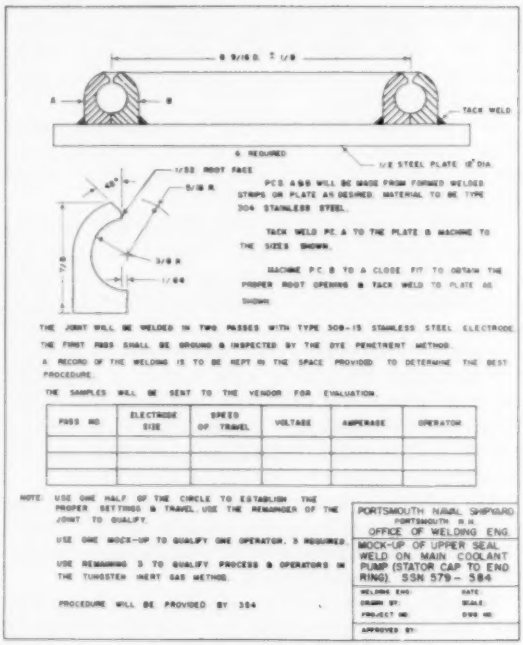

TACK WELD
6 REQUIRED
1/2 STEEL PLATE 18" DIA.
1/32 ROOT FACE
5/16 R.
PC'S A & B WILL BE MADE FROM FORMED WELDED STRIPS OR PLATE AS DESIRED. MATERIAL TO BE TYPE 304 STAINLESS STEEL.
TACK WELD PC. A TO THE PLATE & MACHINE TO THE SIZES SHOWN.
3/8 R.
1/64
MACHINE PC. B TO A CLOSE FIT TO OBTAIN THE PROPER ROOT OPENING & TACK WELD TO PLATE AS SHOWN.
THE JOINT WILL BE WELDED IN TWO PASSES WITH TYPE 308-15 STAINLESS STEEL ELECTRODE.
THE FIRST PASS SHALL BE GROUND & INSPECTED BY THE DYE PENETRANT METHOD.
A RECORD OF THE WELDING IS TO BE KEPT IN THE SPACE PROVIDED TO DETERMINE THE BEST PROCEDURE.
THE SAMPLES WILL BE SENT TO THE VENDOR FOR EVALUATION.
PASS NO.
ELECTRODE SIZE
SPEED OF TRAVEL
VOLTAGE
AMPERAGE
OPERATOR
NOTE: USE ONE HALF OF THE CIRCLE TO ESTABLISH THE PROPER SETTING & TRAVEL. USE THE REMAINDER OF THE JOINT TO QUALIFY.
USE ONE MOCK-UP TO QUALIFY ONE OPERATOR, 3 REQUIRED.
USE REMAINING 2 TO QUALIFY PROCESS & OPERATORS IN THE TUNGSTEN INERT GAS METHOD.
PROCEDURE WILL BE PROVIDED BY 384
PORTSMOUTH NAVAL SHIPYARD
PORTSMOUTH N.H.
OFFICE OF WELDING ENG.
MOCK-UP OF UPPER SEAL WELD ON MAIN COOLANT PUMP (STATOR CAP TO END RING) SSN 579 – 584
WELDING ENG.
DATE
DRAWN BY:
SCALE
PROJECT NO.
DWG NO.
APPROVED BY:

Fig. 5—A mock-up to obtain information for specialized procedure

Welder making fillet welds at inspection port rings of manifolds

Practical Approach to Determine **Weld Size**

provides adequate strength for all types of connections and, at the same time, avoids overwelding

BY OMER W. BLODGETT

Overwelding is one of the major factors of welding cost. Specifying the correct size of weld is the first step in obtaining low-cost welding. It is important then to have a simple method to figure the proper amount of weld to provide adequate strength for all types of connections.

In strength connections, butt welds must be made all the way through the plate, in other words, 100% penetration. Since a butt weld, properly made, has equal or better strength than the plate, there is no need for calculating the stress in the weld or attempting to determine its size. It is necessary to match the weld-metal strength to plate strength when welding alloy steels.

With fillet welds, it is possible to have too small a weld or too large a weld; therefore, it is necessary to be able to determine the proper weld size.

OMER W. BLODGETT is a Design Consultant for the Lincoln Electric Co., Cleveland 17, Ohio.

Paper presented at AWS 40th Annual Meeting held in Chicago, Ill., April 6–10, 1959.

Primary and Secondary Welds

(*a*) Primary welds transmit the entire load at the

particular point where they are located. If the weld fails, the member fails. The weld must have the same property as the member at this point. In brief, the weld becomes the member at this point.

(*b*) Secondary welds simply hold the parts together, thus forming the member. In most cases, the forces on these welds are low.

Parallel and Transverse Welds

(*c*) Parallel welds have forces applied parallel to their axis. In the case of fillet welds, the throat is stressed only in shear. For an equal-legged fillet, the maximum shear stress occurs on the 45-deg throat.

(*d*) Transverse welds have forces applied transversely or at right angles to their axis. In the case of fillet welds, the throat is stressed in both shear and normal (tensile or compressive) stresses. For an equal-legged fillet weld, the maximum shear stress occurs on the $67^1/_2$-deg throat, and the maximum normal stress occurs on the $22^1/_2$-deg throat.

Simple Tensile, Compressive or Shear Loads on Welds

For a simple tensile, compressive or shear load, it is a matter of dividing the given load by the length of the weld to arrive at the applied force, pounds per lineal inch of weld. From this force, the proper leg size of fillet weld or throat of butt weld may be found.

Bending or Twisting Loads on Welds

The problem here is to determine the properties of the welded connection in order to check the stress in the weld without first knowing its leg size. Some design texts suggest assuming a certain weld-leg size and then calculating the stress in the weld to see if it is overstressed or understressed. If the result is too far off, then the weld-leg size is readjusted.

This method has the following disadvantages;

1. Some decision must be made as to what throat section is going to be used to determine the property of the weld. Usually some objection can be raised to any throat section chosen.
2. The resulting stresses must be combined and, for several types of loading, this can be rather complicated.

Description of Terms in Tables and Formulas Used

- b = width of connection, in.
- d = depth of connection, in.
- A = area of flange material held by welds in horizontal shear, in.^{2}
- y = distance between C.G. of flange material and N.A. of whole section, in.
- I = moment of inertia of whole section, in.^{4}
- C = distance to outer fiber, in.
- t = thickness of plate, in.
- J = polar moment of inertia of section, in.^{4}
- P = tensile or compressive load, lb
- V = vertical shear load, lb
- M = bending moment, in.-lb
- T = twisting moment, in.-lb
- A_w = length of weld, in.
- Z_w = section modulus of weld, in.^{2}
- J_w = polar moment of inertia of weld, in.^{2}
- N_x = distance x axis to face
- N_y = distance y axis to face
- S = stress in standard design formula, psi
- f = force in standard design formula when weld is treated as a line, lb per in.
- n = number of welds

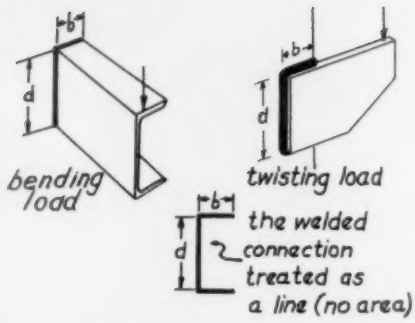


Fig. 1—Treating the weld as a line for a twisting or bending load, A_w = length of weld (in.), Z_w = section modulus of weld (in.^{2}), J_w = polar moment of inertia of weld (in.^{2})

Proposed Method

The following is a simple method to determine the correct amount of welding required for adequate strength for a bending or twisting load. This is a method in which the weld is treated as a line, having no area, but a definite length and outline. This method has the following advantages:

Table 1—Standard Design Formulas Used for Determining Force on Weld

Type of Loading		standard design formula stress lbs/in^2	treating the weld as a line force lbs/in
	PRIMARY WELDS transmit entire load at this point		
	tension or compression	$S = \frac{P}{A}$	$f = \frac{P}{A_w}$
	vertical shear	$S = \frac{V}{A}$	$f = \frac{V}{A_w}$
	bending	$S = \frac{M}{Z}$	$f = \frac{M}{Z_w}$
	twisting	$S = \frac{T\,C}{J}$	$f = \frac{T\,C}{J_w}$
	SECONDARY WELDS hold section together - low stress		
	horizontal shear	$S = \frac{V\,A\,y}{I\,t}$	$f = \frac{V\,A\,y}{I\,n}$
	torsional horizontal shear	$S = \frac{T\,C}{J}$	$f = \frac{T\,C\,t}{J}$

1. It is not necessary to consider throat areas because only a line is considered.
2. Properties of weld are easily found from a table without knowing weld-leg size.
3. Forces are considered on a unit length of weld instead of stresses, thus eliminating the knotty problem of combining stresses.
4. Actual test values of welds are given as force per unit length of weld instead of unit stress on throat of weld.

Treat Weld as a Line

Visualize the welded connection as a single line, having the same outline as the connection, but no cross-sectional area. Notice (Fig. 1) that the area (A_w) of the welded connection now becomes just the length of the weld.

Instead of trying to determine the stress on the weld (this cannot be done unless the weld size is known), the problem becomes a much simpler one of determining the force on the weld.

Use Standard Formulas to Find Force on Weld

When the weld is treated as a line by inserting the property of the welded connection into the standard design formula used for that particular type of load (see Table 1), the force on the weld may be found in terms of pounds per lineal inch of weld.

Example: Bending

Standard design formula (bending stress)		Same formula used for weld (treating weld as a line)	
$S = \frac{M}{Z} = \frac{\text{lb}}{\text{in.}^2}$	*stress*	$f = \frac{m}{Z_w} = \frac{\text{lb}}{\text{in.}}$	*force*

Normally the use of these standard design formulas results in a *unit stress*, psi; however, when the weld is treated as a line, these formulas result in a *force* on the weld, pounds per lineal inch.

For secondary welds, the weld is not treated as a line, but standard design formulas are used to find the force on the weld, pounds per lineal inch.

In problems involving bending or twisting loads, Table 2 is used. It contains the section modulus (Z_w) and polar moment of inertia (J_w) of some 13 typical welded connections with the weld treated as a line.

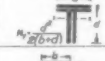
For any given connection, two dimensions are needed, (b) width and (d) depth.

Section modulus (Z_w) is used for welds subjected to bending loads, and polar moment of inertia (J_w) for twisting loads.

Section moduli (Z_w) from these formulas are for maximum force at the top as well as the bottom portions of the welded connections. For the unsymetrical connections shown in the table, maximum bending force is at the bottom.

If there is more than one force applied to the weld, these are found and combined together. All forces which are combined (vectorially added) must occur at the same position in the welded joint.

Table 2—Properties of Welded Connection, Treating Weld as a Line

Outline of Welded Joint (b=width, d=depth)	Bending (about horizontal axis x-x)	Twisting
PROPERTIES OF WELD TREATED AS A LINE		
	$Z_w = \frac{d^2}{6}$ in^2	$J_w = \frac{d^3}{12}$ in^3
	$Z_w = \frac{d^2}{3}$	$J_w = \frac{d(3b^2+d^2)}{6}$
	$Z_w = bd$	$J_w = \frac{b^3+3b^2d}{6}$
	$Z_w = \frac{4bd+d^2}{6}$ top, $= \frac{d^2(4bd+d)}{6(2b+d)}$ bottom	$J_w = \frac{(b+d)^4-b^2d^2}{12(2b+d)}$
	$Z_w = bd + \frac{d^2}{6}$	$J_w = \frac{(2b+d)^3}{12} - \frac{b^2(b+d)^2}{(2b+d)}$
	$Z_w = \frac{2bd+d^2}{3}$ top, $= \frac{d^2(2b+d)}{3(b+d)}$ bottom	$J_w = \frac{(b+2d)^3}{12} - \frac{d^2(b+d)^2}{(b+2d)}$
	$Z_w = bd + \frac{d^2}{3}$	$J_w = \frac{(b+d)^3}{6}$
	$Z_w = \frac{2bd+d^2}{3}$ top, $= \frac{d^2(2b+d)}{3(b+d)}$ bottom	$J_w = \frac{(b+2d)^3}{12} - \frac{d^2(b+d)^2}{(b+2d)}$
	$Z_w = \frac{4bd+d^2}{3}$ top, $= \frac{4bd^2+d^3}{6b+3d}$ bottom	$J_w = \frac{d^3(4b+d)}{6(b+d)} + \frac{b^3}{6}$
	$Z_w = bd + \frac{d^2}{3}$	$J_w = \frac{b^3+3bd^2+d^3}{6}$
	$Z_w = 2bd + \frac{d^2}{3}$	$J_w = \frac{2b^3+6bd^2+d^3}{6}$
	$Z_w = \frac{\pi d^2}{4}$	$J_w = \frac{\pi d^3}{4}$
	$Z_w = \frac{\pi d^2}{2} + \pi D^2$	

Use Allowable Strength of Weld to Find Weld Size

Weld size is obtained by dividing the resulting force on the weld found above by the allowable strength of the particular type of weld used, obtained from Table 3 (steady loads) or Table 4 (fatigue loads).

For a joint which has only a transverse load applied to the weld (either fillet or butt weld), the allowable transverse load may be used from the table. If part of the load is applied parallel (even if there are

Table 3—Allowable Loads per Lineal Inch of Weld (Steady Loads)

Fillet weld (for 1-in. leg fillet weld), lb		Butt weld (for 1-in. thick butt weld), lb	
	Parallel load		
9,600	Building Codes	13,000	Building Codes
8,800	Bridge Codes	11,000	Bridge Codes
9,600	value normally used in machine design	15,000	value normally used in machine design
	Transverse load		
11,300	based upon actual test results	20,000	Building Codes
		18,000	Bridge Codes

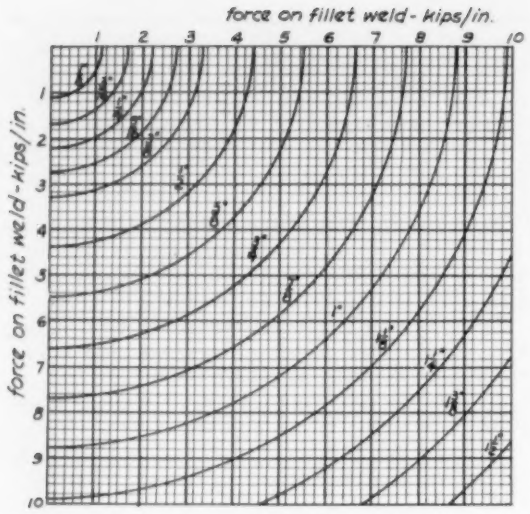


Fig. 2—Leg size of fillet weld for combined forces—AWS Building Code

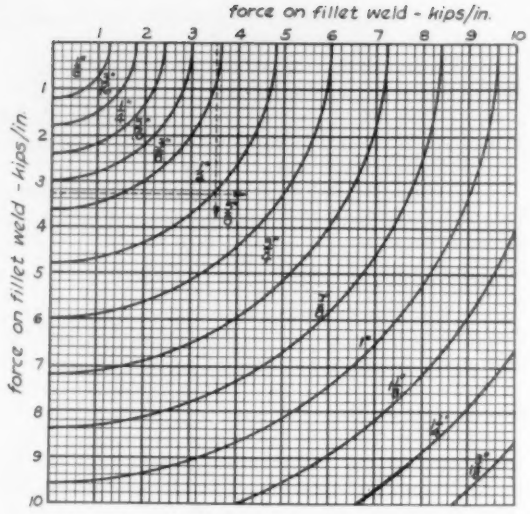


Fig. 3—Leg size of fillet weld for combined forces—AWS Bridge Code

transverse loads in addition) the allowable parallel load must be used.

If there are two forces at right angles to each other on a fillet weld, the charts in Figs. 2 and 3 can be used to combine these forces and indicate the proper fillet-weld-leg size. The chart in Fig. 2 is based upon the AWS Structural Building Code and the chart in Fig. 3 is based upon the AWS Bridge Code.

One important advantage to this method, in addition to its simplicity, is that no new formulas must be used, nothing new must be learned. Assume an engineer has just designed a beam. For strength he has used the standard formula $S = M/Z$. Substituting the load on the beam (M) and the property of the beam (Z) into this formula, he has found the bending stress (S). Now, before leaving this formula, he substitutes the property of the weld, treating it as a line (Z_w), obtained from Table 2, into the same formula, using the same load (M) $f = M/Z_w$ and finds the force on the weld (f) per lineal inch. The weld size is then found by dividing the force on the weld by the allowable force.

Applying System to Any Welded Connection

1. Find the position on the welded connection where the combination of forces will be maximum. There may be more than one which should be considered.

2. Find the value of each of the forces on the welded connection at this point. (*a*) Use Table 1 for the standard design formula to find the force on the weld. (*b*) Use Table 2 to find the property of the weld treated as a line.

3. Combine (vectorially) all of the forces on the weld at this point.

4. Determine the required weld size by dividing this value (3) by the allowable force in Tables 3 or 4.

Horizontal Shear Forces on Weld Are Usually Low

Any weld joining the flange of a beam to its web is stressed in horizontal shear (Fig. 4). Normally a designer is accustomed to specifying a certain size

Table 4—Allowable Fatigue Strength

	2,000,000 cycles	600,000 cycles	100,000 cycles	But Not to Exceed
BASE METAL TENSION CONNECTED BY FILLET WELDS	$\frac{7500}{1-2/3K}$ psi 10,000	$\frac{10,500}{1-2/3K}$ psi 14,000	$\frac{15,000}{1-2/3K}$ psi 18,000	$\frac{P}{1-\frac{K}{2}}$ psi
BASE METAL COMPRESSION CONNECTED BY FILLET WELDS	$\frac{7500}{1-2/3K}$ psi	$\frac{10,500}{1-2/3K}$ psi	$\frac{15,000}{1-2/3K}$ psi	$\frac{P}{1-\frac{K}{2}}$ psi
BUTT WELD TENSION	$\frac{13,500}{1-\frac{K}{2}}$ psi	$\frac{15,000}{1-\frac{K}{2}}$ psi	$\frac{18,000}{1-\frac{K}{2}}$ psi	18,000 psi
BUTT WELD COMPRESSION	$\frac{18,000}{1-K}$ psi	$\frac{18,000}{1-.8K}$ psi	$\frac{18,000}{1-\frac{K}{2}}$ psi	P psi
BUTT WELD SHEAR	$\frac{9,000}{1-\frac{K}{2}}$ psi	$\frac{10,000}{1-\frac{K}{2}}$ psi	$\frac{12,000}{1-\frac{K}{2}}$ psi	13,000 psi
FILLET WELDS	$\frac{5040}{1-\frac{K}{2}}$ lb./in.	$\frac{7070}{1-\frac{K}{2}}$ lb./in.	$\frac{8484}{1-\frac{K}{2}}$ lb./in.	8760 lb./in.

AWS Par. 208 1956 Bridges $K = \frac{\text{min.}}{\text{max.}}$

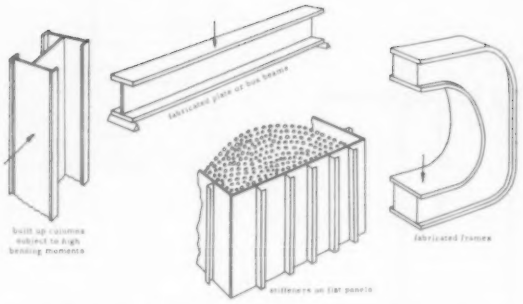

built up columns subject to high bending moments
fabricated plate of box beams
stiffeners on flat panels
fabricated frames

Fig. 4—These welds are stressed in horizontal shear and the forces on them can be determined

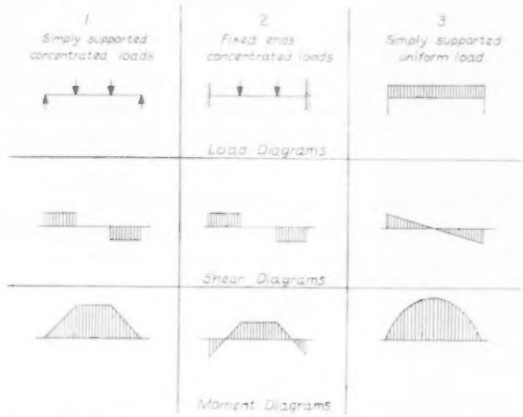


Fig. 5—The shear diagram is a picture of the amount and location of the welding required for horizontal shear. Beam No. 1 is simply supported with two equal concentrated loads; beam No. 2 has fixed ends and two equal concentrated loads; beam No. 3 is simply supported with a uniform load

fillet weld for a given plate thickness (leg size about $^3/_4$ of the plate thickness) in order for the weld to have full plate strength. However this particular joint between the flange and web is one exception to this rule. In order to prevent web buckling, a lower allowable shear stress is usually used; this results in a thicker web. The welds are in an area next to the flange where there is no buckling problem and, therefore, no reduction in allowable load is used for them. From a design standpoint, these welds may be very small, their actual size sometimes determined by the minimum allowed because of the thickness of the flange plate, in order to assure the proper slow cooling rate of the weld on the heavier plate.

General Rules About Horizontal Shear

Outside of simply holding the flanges and web of a beam together, or to transmit any unusually high force between the flange and web at right angles to the member (for example, bearing supports, lifting lugs, etc.), the real purpose of the weld between the flange and web is to transmit the horizontal shear forces, and the size of the weld is determined by the

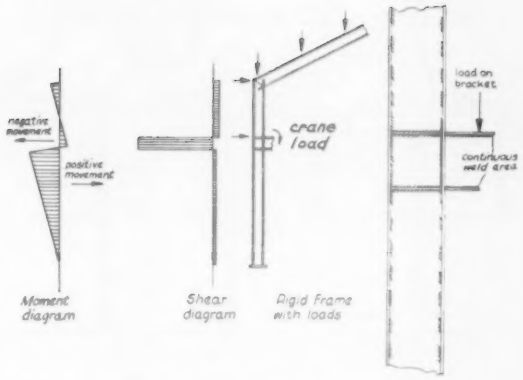


Fig. 6—Shear diagram indicates where the amount of welding is critical

value of these shear forces.

It will help in the analysis of a beam if the shear diagram is used as a picture of the amount and location of the welding required between the flange and web (Fig. 5).

A study of Fig. 5 will show that (1) loads applied transversely to members cause bending moments; (2) changing bending moments cause horizontal shear forces; (3) horizontal shear forces require welds to transmit these forces between the flange and web of the beam.

Notice that (1) shear forces occur only when the bending moment is changing. (2) It is quite possible for portions of a beam to have little or no shear—notice the middle portions of beams 1 and 2—this is because the bending moment is constant within this area. (3) When there is a difference in shear along the length of the beam, the shear forces are usually greatest at the ends of the beam (see beam 3). This is why stiffeners are sometimes welded continuously at their ends for a distance even though they are welded intermittently the rest of their length. (4) Fixed ends will shift the moment diagram so that the maximum moment is less. What is taken off at the middle of the beam is added to the ends. Even though this does happen, the shear diagram remains unchanged, so that the amount of welding between the flange and web will be the same.

To apply these rules, consider the welded frame in Fig. 6. The moment diagram for this loaded frame is shown on the left-hand side. The bending moment is gradually changing throughout the vertical portion of the frame. The shear diagram shows that this results in a small amount of shear in the frame. Using the horizontal shear formula [$f = Vay/In$], this would require a small amount of welding between the flange and web. Intermittent welding would probably be sufficient. However, at the point where the crane bending moment is applied, the moment diagram shows a very fast rate of change. Since the shear value is equal to the rate of change in the bending moment, it is very high and more welding is required at this region.

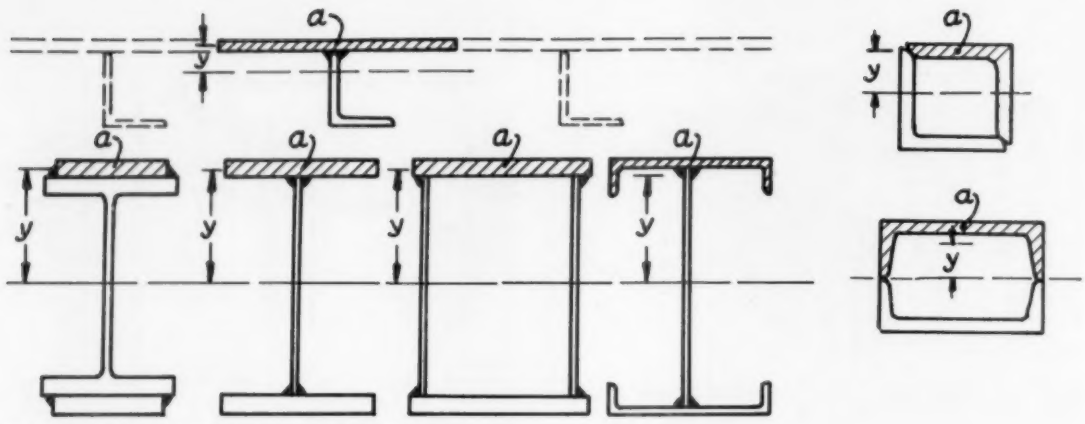


Fig. 7—Examples of welds in horizontal shear

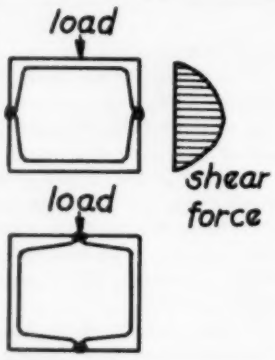


Fig. 8—Welds should be located at point of minimum stress. Shear force on the weld in the top example is high because the weld lies on the neutral axis of the section where the horizontal shear force is maximum. Shear force in bottom example is taken by the plate and not the weld; therefore, the shear formula is not used since there is no load on the weld. Full penetration is not needed

General Rule

Use continuous welding where loads or moments are applied to a member, even though intermittent welding may be used throughout the rest of the fabricated frame.

Application of Rules to Find Weld Size

The horizontal shear forces acting on the weld joining a flange to web (see Figs. 7 and 8) may be found from the following formula:

$$f = \frac{Vay}{In} \text{ (lb/lin in.)}$$

where:

f = force on weld, lb/lin in.
V = total shear on section at a given position along the beam, lb

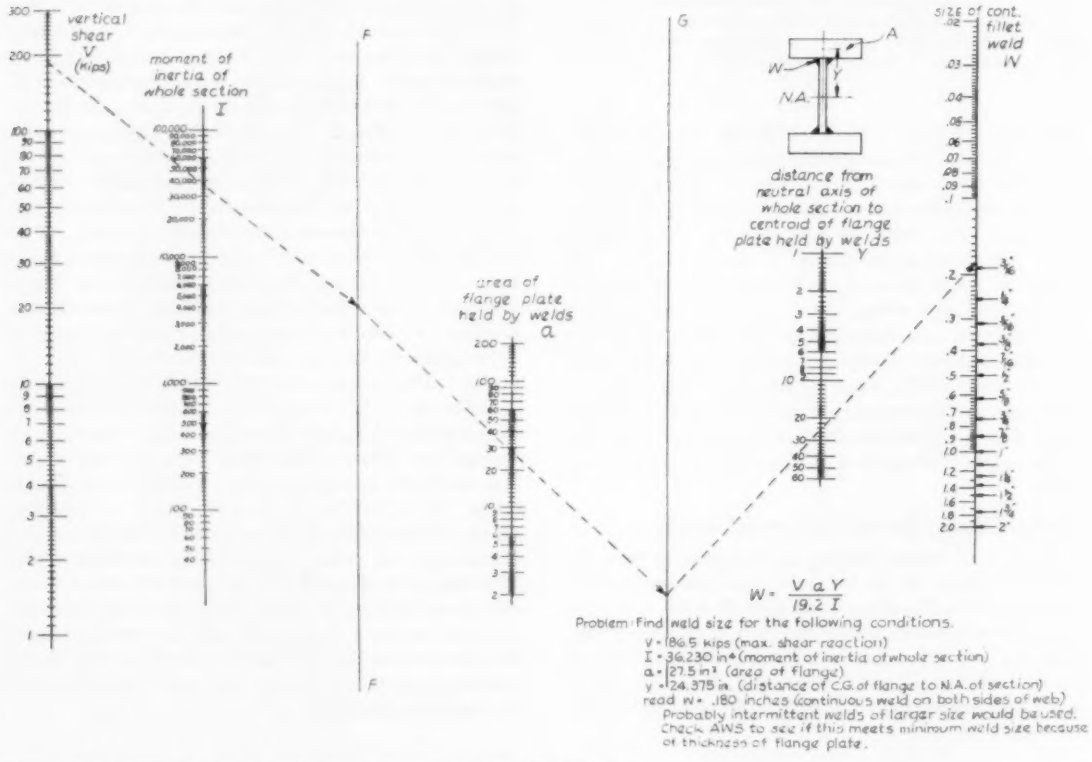

vertical shear V (kips)
moment of inertia of whole section I
area of flange plate held by welds a
distance from neutral axis of whole section to centroid of flange plate held by welds Y
size of cont. fillet weld W
N.A.
W = V a Y / 19.2 I
Problem: Find weld size for the following conditions.
V = 86.5 kips (max. shear reaction)
I = 36,230 in⁴ (moment of inertia of whole section)
a = 27.5 in² (area of flange)
y = 24.375 in. (distance of C.G. of flange to N.A. of section)
read W = .180 inches (continuous weld on both sides of web)
Probably intermittent welds of larger size would be used.
Check AWS to see if this meets minimum weld size because of thickness of flange plate.

Fig. 9—Nomograph for size of weld joining flange to web of fabricated beam

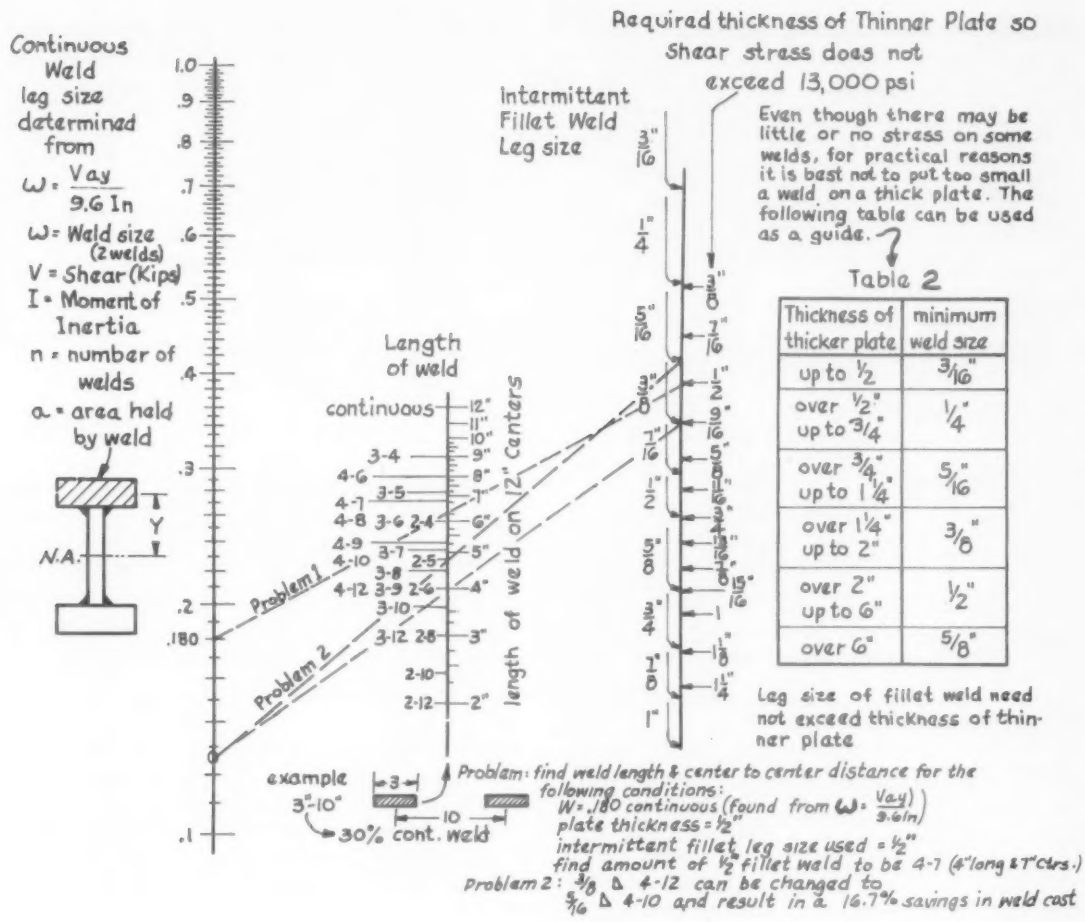

Continuous Weld leg size determined from
ω = Vay / 9.6 In
ω = Weld size (2 welds)
V = Shear (Kips)
I = Moment of Inertia
n = number of welds
a = area held by weld
N.A.
Y
Problem 1
Problem 2
Length of weld
continuous
Length of weld on 12" Centers
example
3"-10"
30% cont. weld
Required thickness of Thinner Plate so Shear stress does not exceed 13,000 psi
Intermittant Fillet Weld Leg size
Even though there may be little or no stress on some welds, for practical reasons it is best not to put too small a weld on a thick plate. The following table can be used as a guide.
Table 2
Thickness of thicker plate | minimum weld size
up to 1/2 | 3/16"
over 1/2" up to 3/4" | 1/4"
over 3/4" up to 1 1/4" | 5/16"
over 1 1/4" up to 2" | 3/8"
over 2" up to 6" | 1/2"
over 6" | 5/8"
Leg size of fillet weld need not exceed thickness of thinner plate
Problem: find weld length & center to center distance for the following conditions:
W = .180 continuous (found from ω = Vay / 9.6In)
plate thickness = 1/2"
intermittent fillet leg size used = 1/2"
find amount of 1/2" fillet weld to be 4-7 (4" long & 7" Ctrs.)
Problem 2: 3/8 Δ 4-12 can be changed to 5/16 Δ 4-10 and result in a 16.7% savings in weld cost

Fig. 10—Nomograph for size and spacing of intermittent fillet welds

a = area of the flange held by weld, sq in.
y = distance between center of gravity of the flange area and the neutral axis of the whole section, in.
I = moment of inertia of whole section, in.^{4}
n = number of welds joining the flange to web

Nomograph to Calculate Weld Size

The nomograph in Fig. 9 may be used to find the required weld size. This is based upon two welds being used, one on each side of the web.

If a continuous fillet weld is to be used, read the weld size on the right-hand side to the next largest fraction of an inch.

Determination of Length and Spacing of Intermittent Welds

If intermittent fillet welds are to be used, read the weld size as a decimal and divide this by the actual size used. When expressed as a percentage, this will give the length of weld to be used per unit length. For convenience, Table 5 has various intermittent weld lengths and distances between centers for given percentages of continuous welds.

$$\% = \frac{\text{calculated leg size (continuous)}}{\text{actual leg size used (intermittent)}}$$

Table 5—Length and Spacing of Intermittent Welds

Continuous weld, %	Length of intermittent welds and distance between centers, in.		
75	..	3–4	..
66	..	..	4–6
60	..	3–5	..
57	..	..	4–7
50	2–4	3–6	4–8
44	..	..	4–9
43	..	3–7	..
40	2–5	..	4–10
37	..	3–8	..
33	2–6	3–9	4–12
30	..	3–10	..
25	2–8	3–12	..
20	2–10	..	..
16	2–12	..	..

EXAMPLE: Find fillet weld size for following connection

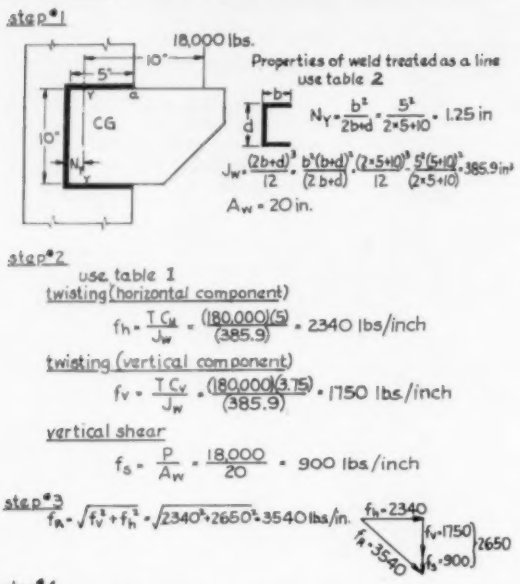

step*1
18,000 lbs.
10"
5"
Properties of weld treated as a line
use table 2
CG
10"
$N_Y = \frac{b^2}{2b+d} = \frac{5^2}{2\times5+10} = 1.25$ in
$J_w = \frac{(2b+d)^3}{12} - \frac{b^2(b+d)^2}{(2b+d)} = \frac{(2\times5+10)^3}{12} - \frac{5^2(5+10)^2}{(2\times5+10)} = 385.9$ in³
$A_w = 20$ in.
step*2
use table 1
twisting (horizontal component)
$f_h = \frac{T C_H}{J_w} = \frac{(180,000)(5)}{(385.9)} = 2340$ lbs/inch
twisting (vertical component)
$f_v = \frac{T C_V}{J_w} = \frac{(180,000)(3.75)}{(385.9)} = 1750$ lbs./inch
vertical shear
$f_s = \frac{P}{A_w} = \frac{18,000}{20} = 900$ lbs./inch
step*3
$f_R = \sqrt{f_v^2 + f_h^2} = \sqrt{2340^2 + 2650^2} = 3540$ lbs/in.
$f_h = 2340$
$f_v = 1750$
2650
$f_R = 3540$
$f_s = 900$
step*4
$w = \frac{3540}{9600} = .368$ inch or $\frac{3}{8}$ inch leg fillet weld

Fig. 11—Sample problem using steps outlined in this approach to determining weld size

EXAMPLE: Determine the size of welds joining the 4" flange plate to the 1½ web plates on this large welded press frame which must withstand a 750 ton vertical load.

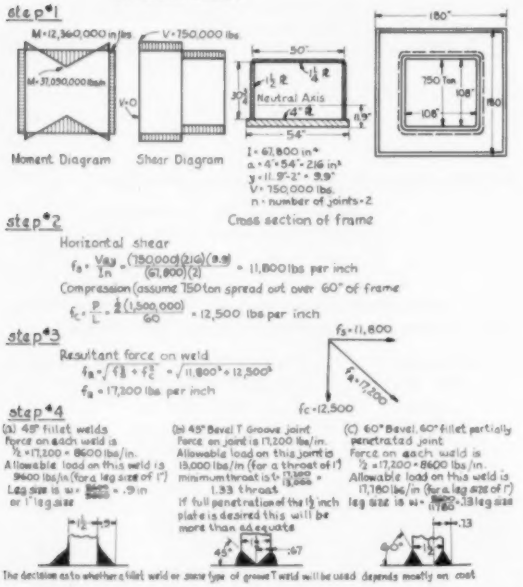
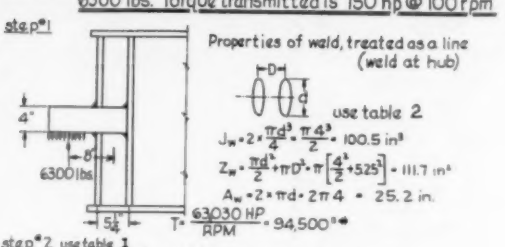

step*1
M=12,360,000 in lbs
V=750,000 lbs
M=31,050,000 in lbs
V=0
Moment Diagram
Shear Diagram
50"
1½ ℓ
1¼ ℓ
Neutral Axis
4" ℓ
54"
I = 61,800 in⁴
a = 4"×54" = 216 in²
y = 11.5"-2" = 9.5"
V = 750,000 lbs.
n = number of joints = 2
Cross section of frame
180"
750 Ton
108"
108"
110"
step*2
Horizontal shear
$f_s = \frac{V a y}{I n} = \frac{(750,000)(216)(9.5)}{(61,800)(2)} = 11,800$ lbs per inch
Compression (assume 750 ton spread out over 60" of frame
$f_c = \frac{P}{L} = \frac{\frac{1}{2}(1,500,000)}{60} = 12,500$ lbs per inch
step*3
Resultant force on weld
$f_R = \sqrt{f_s^2 + f_c^2} = \sqrt{11,800^2 + 12,500^2}$
$f_R = 17,200$ lbs per inch
$f_s = 11,800$
$f_R = 17,200$
$f_c = 12,500$
step*4
(a) 45° fillet welds
Force on each weld is
½ × 17,200 = 8600 lbs/in.
Allowable load on this weld is 9600 lbs/in (for a leg size of 1")
Leg size is $w = \frac{8600}{9600} = .9$ in or 1" leg size
(b) 45° Bevel T Groove joint
Force on joint is 17,200 lbs/in.
Allowable load on this joint is 13,000 lbs/in (for a throat of 1")
minimum throat is $t = \frac{17,200}{13,000} = 1.33$ throat
If full penetration of the 1½ inch plate is desired this will be more than adequate
45°
.67
(c) 60° Bevel, 60° fillet partially penetrated joint
Force on each weld is
½ × 17,200 = 8600 lbs/in.
Allowable load on this weld is 17,160 lbs/in (for a leg size of 1")
leg size is $w = \frac{8600}{17,160} = .13$ leg size
60°
.13
The decision as to whether a fillet weld or some type of groove T weld will be used depends mostly on cost

Fig. 12—In this problem vertical portions of press frame have a constant bending moment and, therefore, no shear reaction. Main requirements for welds occur only in horizontal portion; welds in vertical portion only have to hold sections together

EXAMPLE: Find fillet weld size for hub with a bearing load-6300 lbs. Torque transmitted is 150 hp @ 100 rpm


step*1
Properties of weld, treated as a line
(weld at hub)
D
d
use table 2
4"
6300 lbs
8"
5¼"
$J_w = 2\times\frac{\pi d^3}{4} = \frac{\pi 4^3}{2} = 100.5$ in³
$Z_w = \frac{\pi d^2}{2} + \pi D^2 = \pi\left[\frac{4^2}{2} + 5^2\right] = 111.7$ in²
$A_w = 2\times\pi d = 2\pi 4 = 25.2$ in.
$T = \frac{63030\ HP}{RPM} = \frac{63030\times150}{100} = 94,500$ in-lbs

step*2 use table 1

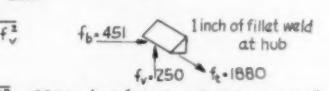
bending: $f_b = \frac{M}{Z_w} = \frac{6300\times8}{111.7} = 451$ lbs/inch

twisting: $f_t = \frac{T_c}{J_w} = \frac{94,500\times2}{100.5} = 1880$ lbs/inch

vertical shear: $f_v = \frac{V}{A_w} = \frac{6300}{25.2} = 250$ lbs/inch

step*3

$f_R = \sqrt{f_b^2 + f_t^2 + f_v^2}$



$f_R = \sqrt{451^2 + 1880^2 + 250^2} = 1950$ lbs/inch (actual resultant force on weld)

Since this is fatique loading - assume N = 2,000,000 cycles and use formula 10 of Table 4 - assume in this case a complete reversal of load, hence $K = \frac{min}{max} = -1$ and allowance force would be

$f = \frac{5090}{1-\frac{K}{2}} = \frac{5090}{1+\frac{1}{2}} = 3370$ lbs/inch (allowable)

step*4

leg size $W = \frac{1950}{3370} = .58$" or use $\frac{5}{8}$ inch leg fillet weld

Fig. 13—Weld-size problem involving bending and twisting

Nomograph to Calculate Intermittent Weld Size

The nomograph in Fig. 10 will be helpful in deciding the spacing of intermittent welds after the required continuous weld size has been determined.

The left-hand axis is the required continuous fillet-weld size determined from the formula:

$$w = \frac{Vay}{2 \times 9600 \times I}$$

The right-hand axis is the size of intermittent fillet weld used. It is important that the leg size of weld used in determining weld spacing is not so large that it will overstress the plate. Sometimes the allowable shear stress in the web of the plate girder is held to 13,000 psi. Therefore, in this case, the maximum leg size of fillet weld used for design should not exceed two-thirds of the web thickness. Be sure that the actual weld-leg size chosen on this right-hand axis does not indicate a greater plate thickness than the web of the girder. If so, then move upward along this axis to the actual web thickness and use this value to determine proper weld spacing. The middle axis is the resulting weld spacing expressed as a length of intermittent weld and distance between centers. Also on this axis is the required length of intermittent weld for 12-in. centers.

To use this nomograph, draw a line between the left axis (calculated fillet weld-leg size if continuous) and the right axis (actual intermittent weld-leg size used or the thickness of web) taking into account the information in Table 5. The proper weld spacing is read on the middle axis.

Practical Welder and Designer

America's "Ace in the Hole"—Atomic Submarines

BY GEORGE W. KIRKLEY AND SHERMAN R. POPPEN

Fig. 1—Piping for the nuclear-power plant of an atomic submarine is welded with a tungsten-arc torch. Liquid-argon cylinder in the background supplies argon as a shielding gas for the weld pool and a purge for the inside of the pipe—protecting both sides from contamination

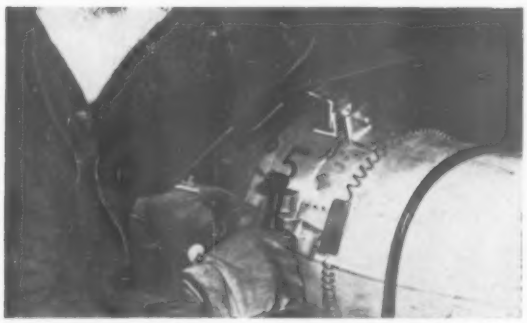


Fig. 2—A welder uses a tungsten-arc torch to join stainless-steel piping. Figures 1 and 2 illustrate a main reason why tungsten-arc welding was chosen for this work: the process can be used on small- and large-diameter pipe with the same technique to produce the same high-quality welds

One hundred years ago, in *20,000 Leagues Under the Sea*, Jules Verne envisioned a powerful undersea craft which roamed the ocean depths. He called it the "Nautilus." Although his vision of the "Nautilus" became reality, he could not envision its effect on the world of its time: launching of the atomic submarine U.S.S. *Nautilus* brought a new plateau in the advancement of the Atomic Age. To fully understand the meaning of this advancement requires a study of the atomic submarine in three areas: production problems, economic effects and national defense.

Production Problems

At their Groton, Conn. yards, Electric Boat Division of General Dynamics Corp. has produced three atomic submarines, including the *Nautilus*, with six either presently under construction or awaiting commissioning. Throughout this undertaking, the basic tenets of production have been followed. For example, one of the most intricate (and potentially expensive) jobs on an atomic sub is its complex stainless-steel nuclear piping system. Here, a consumable-insert method for root-pass welding of pipe and the gas-shielded tungsten-arc process were applied.

The reasons for selecting the tungsten-arc process were simple: tungsten-arc welding with consumable inserts produced consistently higher-quality welds at a low cost; tungsten-arc welding could be used at high speeds on both small- and large-size piping with the same techniques and required less operator skill to obtain high-quality results; and the tungsten-arc welds met the severest requirements without grinding or machining the inside of the pipe (Figs. 1 and 2).

GEORGE W. KIRKLEY is a Welding Engineer, Electric Boat Division of General Dynamics Corp., Groton, Conn., and SHERMAN R. POPPEN is a Welding Sales Engineer, Linde Co., Boston, Mass.

Fig. 3—The USS Skipjack under construction at the Groton, Conn., yards of Electric Boat. Already launched, the Skipjack is the most streamlined of all atomic submarines

Fig. 4—First atomic sub (USS Nautilus)—The world's first nuclear-powered submarine enters the waters of the Thames River at Groton, Jan. 12, 1954. The Nautilus measures 319 ft and displaces 3000 tons

Tungsten-arc welding was the best process from the standpoint of speed, cost and quality. (In fact, the speed of tungsten-arc welding, combined with production improvements at the Groton yards, helped Electric Boat complete the U.S.S. *Skate* seven months ahead of schedule.) Argon gas, supplied from a liquid argon cylinder, was used for shielding purposes (Fig. 1).

Economic Effects

The effect of atomic submarines (and defense spending in general) on the nation's economy has been revolutionary. To bear this out, take the situation at Electric Boat. As a result of construction of atomic submarines, 4000 new jobs were created at the Groton yards. If one considers the more than 2000 additional suppliers and subcontractors working on the submarine, more than 8000 new jobs were created.

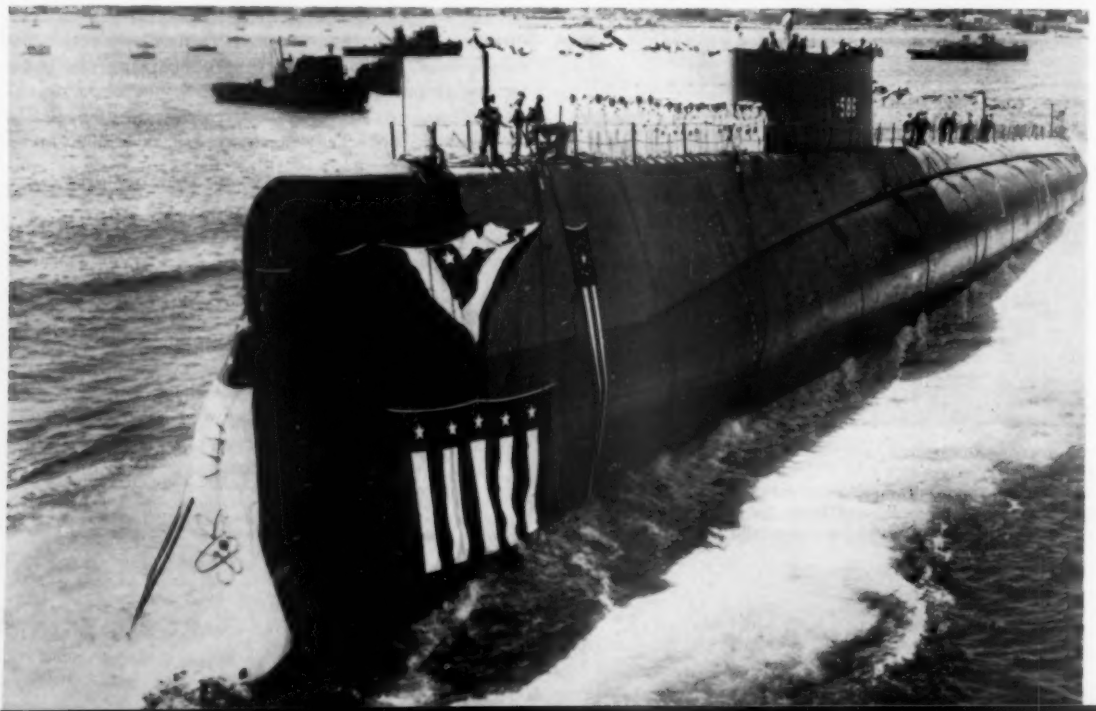
But, atomic submarines are just one part of a huge program. For instance, the $106,400,000 contract for the U.S.S. *Triton* (Fig. 5), largest of the atomic subs, was just 1.4% of the Navy's prime contracts let in 1958. If the entire military budget is considered, the *Triton* contract was just 0.2% of the nation's defense spending in 1958.

National Defense

Since much information on America's atomic submarine remains classified, only a guess can be made at their true value. A brief résumé of the improvements in atomic subs, however, goes a long way toward "filling in between the lines."

Consider the U.S.S. *Skipjack*—most streamlined

Fig. 5—Largest atomic sub (USS Triton)—The world's largest and most powerful submarine is launched at Groton, Aug. 19, 1958, before a record throng of 30,000 persons. The Triton displaces 5900 tons, and is 447 ft long with a beam of 37 ft. The Triton is the first ship in history with twin nuclear-power plants, three deck levels within the hull, and dial-telephone communications



of the atomic subs (Figs. 3 and 6). The *Skipjack* is a submarine that can outperform the fish. A shark-like hull design, propelled by an atomic reactor, enables the *Skipjack* to attain the same dominance under water that modern supersonic jets hold in the air.

In 1900, John Philip Holland, "father" of the American submarine force, sold the Navy its first submarine, the U.S.S. *Holland*. It was a small craft, sleek, streamlined and heavy around the waistline. There were no bulges to retard speedy underwater travel. It slid through the deep. Its only drawback was a primitive, gasoline-electric drive that forced the submarine to spend most of its time on the surface. Although the *Holland* didn't have the internal chemistry to stay under water, the perfect submarine shape was ready over half a century before the atomic-powered engine.

"Father" of the *Skipjack* was the *Nautilus*, its "mother" was the *Albacore*. The *Nautilus*, first of the A-sub line, proved the success of atomic power for propulsion (Fig. 4). The *Albacore*, an experimental, diesel-electric sub designed along the lines of the original *Holland*, showed that a trim design means everything when it comes to fast underwater travel. The *Skipjack* has inherited the almost endless power of the *Nautilus* and the speed and maneuverability of the *Albacore*.

The *Skipjack* is nervous and skittish on the surface. Her rounded nose and broad beam force her to plow into the water for every foot of a surface cruise. But General Dynamics' engineers can only guess at her top *underwater* speed. Conversations about her are more like airplane shoptalk. *Skipjack* is "flown" not steered. She has a one-man "joy stick" control. Her underwater maneuvers are already spoken of as "hydrobatics."

Somewhat smaller (250 ft long) than the average atomic sub, the *Skipjack* represents a major breakthrough in all aspects of naval architecture. Even such reliable submarine fixtures as the bow planes have been shifted and now project from the conning tower like two stubby wings. Repositioning of these driving planes keeps them away from turbulence created by water flowing along the hull. They remain aloft in less agitated "clean" water.

Formerly, submarine superstructure was as decorative as a victorian mansion. Radar masts, sonar domes, winches, deck guns and other gear provided *brakes* on underwater speed. World War II submarines were nothing more than fast surface ships. They could make 21 mph on the surface, but top underwater run of 13 mph meant only an hour of performance before it was necessary to resurface and charge their batteries—sitting ducks for planes and antisubmarine vessels.

Submarine streamlining began after the war when the battleworn fleet submarines were transformed into "guppys." This meant smoothing out the conning tower and transforming it into a sail, installing snorkel systems and rounding over the hull. Deck guns were also eliminated. As newer subs were built they became cleaner and less gawky in shape.

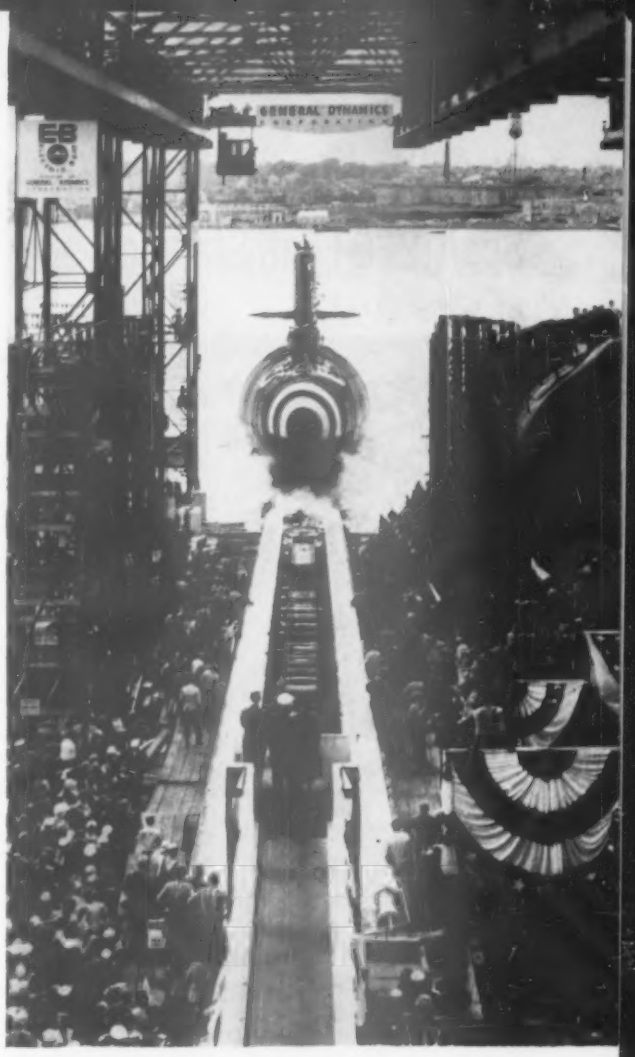


Fig. 6—Fastest atomic sub (USS Skipjack)—The world's fastest and most streamlined submarine glides into the Thames, May 26, 1958. Her measurements : length, 250 ft; beam, 29 ft; displacment, 3000 tons; range, over 60,000 mi.

To date, the *Skipjack* is the ultimate. She has no projections. Everything that is necessary on her superstructure has been recessed or made retractable. With the enormous power of her nuclear engines she can hit speeds that were previously only spoken of in jest, and can remain submerged indefinitely.

Previously, submarines had to rely upon complete silence to escape destruction and thus became known as the "Silent Service." But with atomic submarines, the Navy has vessels that are both silent *and swift*. No longer will submarines fire only at slow-moving targets. They will be able to pace and pass the fastest of surface vessels. Coupled with ballistic missiles, such as the Polaris, atomic submarines are one of the most powerul defensive and offensive weapons ever devised for ocean warfare—they are truly America's "ace in the hole."

Welded-Plate-Girder Arches Span 226-Foot Stadium

BY E. B. REEVES

Fig. 1—Arc-welded plate girders, eight at each end and five continuous spans at the sides, are tied together by cross framing which supports purlins. Entire exterior is covered with sheet copper, converting an open stadium to a $1.5 million exhibition building

Over 900 tons of arc-welded structural steel went into the giant "umbrella" over an 8000-seat concrete stadium at the Louisiana State Fair Grounds, Shreveport, La., comprising a $960,000 addition (Fig. 1). It is now known as the State Fair Youth Activities Building, representing a $1.5 million plant. Exterior roof and walls are sheathed completely in sheet copper, making the structure a brilliant and enduring landmark.

Basic frame elements, illustrated herewith, are five huge continuous plate-girder arches with a span of 226 ft, rising to a center height of 82 ft and with arch length of approximately 280 ft. At either end of the building are eight radial half-arches, of the same general size and construction as the side members, pinned at their upper ends to a large spider bracket. The 26 lower ends of the girders are either pinned or bolted to heavy shoes of welded-steel plate, attached to ground level foundation piers.

Tying the arches together transversely are seven equispaced horizontal rows of open-web crossframes, extending completely around the building and bolted to stiffener plates of the successive girders. Finally, three rows of variable-section purlins are laid over the crossframes, paralleling the girders and forming a flush supporting surface for the roofing sheet.

The arena is 120 ft wide, 240 ft long, and is surrounded by a continuous tier of 19 rows of seats inside the framing members, rising to a height of 35 ft at the rear. Thus, ample space is available for football, track and field events, livestock exhibits and other spectacles associated with state fairs.

Unusual design of the half-arches was made possible only by welded-steel-plate fabrication. There are four shop-welded splices along the length, alternated with four field splices, made as erection proceeded from base to top center. Web depth and thickness varies from 3 ft at the base, flaring to 10 ft, 9 in. at the "knee" and tapering to 6 ft for the balance of the length; thickness is $1/2$ in. on lower sections, $3/8$ in. across the top. Flanges are $14\,1/2$ in. wide, top and bottom, with $1\,1/8$ in. thickness on the side arches, $9/16$ in. on the end units which are slightly shorter. Stiffener plates are $3/8$ in. thick, 5 in. deep, welded to flanges and web with $1/4$-in. fillets, and placed directly opposite each other about every 4 ft along the web. Each main girder arch required 156 stiffeners.

A typical field splice is shown in Fig. 2. It will be noted that both web and flanges are drilled for bolting on four alignment plates to the undersides of the flanges and to the web. Flanges and web are beveled at 45 degrees on one side of the joint for a single-vee groove weld, while the web is notched or coped on one side of the lower edge to permit uninterrupted welds across the lower flange. After field welds are made, the bolts are removed and the holes filled with rivets. The $3/4$-in. alignment plate on the lower flange remains in place permanently; other plates—on the web and underside of top chord—are removed.

Three crawler cranes were used to hoist girder elements into position for welding. Welding crews were stationed on platforms slung from the girders and found the operation rather precarious in the early stages before a full arch had been completed and the crossframes had been connected.

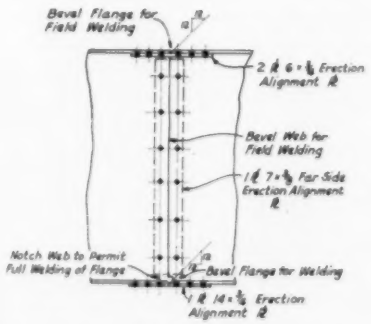

Bevel Flange for Field Welding
2 Pl 6 × ⅜ Erection Alignment Pl
Bevel Web for Field Welding
1 Pl 7 × ⅜ Far Side Erection Alignment Pl
Notch Web to Permit Full Welding of Flange
Bevel Flange for Welding
1 Pl 14 × ⅜ Erection Alignment Pl

Fig. 2—Sketch of a typical field splice, of which there are four in each half-arch, supplemented by four shop-welded splices. Drilled holes are for bolting on alignment plates. After welds are made, plates are removed, except on lower flange, and holes filled by rivets

E. B. REEVES is District Engineer, the Lincoln Electric Co., Shreveport, La.

Welded Studs Secure Insulation and Lagging for High-Temperature Boiler

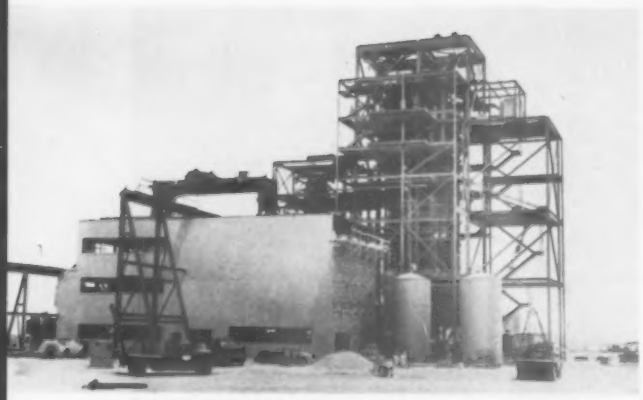


Fig. 1—End-welded studs were used to secure high-temperature insulation and lagging around the boiler of this new Reeves Station of the Public Service Co. of New Mexico. The studs also were used to secure field-assembled insulation sandwich wall, shown here on the side of the plant building

Fig. 2—With this stud-welding gun, steel studs were end-welded to girts at the rate of several per minute. Inner and outer sheets of aluminum, along with fiberglas insulation, were then impaled on the studs to form a highly economical field-assembled curtain wall

Fig. 3—End-welded studs are shown on pressure casing of boiler. Magnesia block insulation and aluminum lagging were impaled over studs and topped off with special caps

Substantial savings in over-all construction cost, and several corollary benefits, were realized when end-welded studs were used recently for the first time to secure insulation and lagging for a high-temperature, pressurized power-plant boiler (Fig. 1).

At the new Reeves Station being constructed near Albuquerque for the Public Service Co. of New Mexico, stainless-steel studs were first end-welded in organized patterns to the pressure casing of the boiler. Several studs were welded per minute with a stud-welding gun (Fig. 2). Two 2-in.-thick layers of magnesia block insulation were fitted over the studs and made snug against the pressure casing (Fig. 3). Ribbed embossed aluminum lagging, 0.032-in. thick, was then impaled over the studs.

This idea not only brought important economies during construction, but it is also expected to cut maintenance costs during the life of the plant.

Another out-of-the-ordinary feature of Reeves Station is colored aluminum insulated sandwich wall, which saved approximately 15% over conventional sandwich walls. Assembled on the job, it was used for both the administration building and the main power-plant building. Additional savings were realized because the aluminum needed no paint.

Stainless-steel studs, end-welded in the field to building girts, also secured the curtain wall. It is comprised of an interior sheet of 0.032-in. corrugated aluminum, insulation of 1-in. fiberglass, and exterior siding, with an alodine green finish, of 0.032-in. ribbed embossed aluminum.

To help hold the boiler insulation in place, 1-in. wide, light-gage aluminum strips were stretched over the magnesia blocks and impaled on the studs, then secured with speed clips. All buck stays were covered with aluminum wrappers, also impaled on studs, which then served as flashing. When the lagging was in place, aluminum caps were applied to the studs.

The studs provided vertical support for the insulation at many points, thus eliminating the need for special means of holding the magnesia block in place.

Another significant stud-welding application on this project was the use of $^{7}/_{8}$-in.-diam threaded studs which secure the rails for a gantry crane located on top of the main power-plant building. These studs were end welded to structural steel. The rails rest on the steel and are fastened by clips that fit over the rail base flanges. The clips are fitted over the studs and are held in place by standard machine nuts.

Based on a story by the Nelson Stud Welding Division, Gregory Industries, Inc., Lorain, Ohio.

Fig. 1—After nearly three years of operation—including carriage of trucks with as much as 8000 lb per wheel—the seven-lane car deck of the **Evergreen State** ferry is still smooth and level

Fig. 2—To eliminate "dishing" of deck plates by trucks and automobiles carried by the **Evergreen State** ferry boat, 12-in. lightweight beams were slit to form "T's" and welded to the underside of deck plating on $13^1/_2$-in. centers

Slit "T's" and Welding Strengthen Deck Framing . . . Without Increasing Weight

After nearly three years of operation under heavy load conditions, the seven-lane car deck of the world's largest double-end all-steel ferry is still smooth and level—because of the material used in deck framing and the manner in which that material was employed.

The ferry boat is the 310-ft, 1495-ton *Evergreen State* (see Fig. 1). The car-passenger vessel is operated by the Washington State Toll Bridge Authority in Puget Sound. It plies the seven miles between Seattle and Winslow, Wash.

The heavy-duty part of the ferry is the car deck. To eliminate "dishing" of deck plates due to the heavy truck loads encountered, the deck framing was doubled. Instead of using old-style heavy channel or angle iron on standard 27-in. centers, lightweight structural beams were specified. These were split to form "T's" and welded to the underside of the deck plating on $13^1/_2$-in. centers (see Fig. 2). In this way, the deck framing was doubled without increase in weight.

Based on a story by Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Lightweight beams were also used as framing beneath the passenger and Texas decks of the boat, and as stiffeners in the two pilot houses atop the Texas deck. By using them, the two prime requirements in ferry-boat design—light weight and stability—were met.

The decks were built in subassemblies as the hull construction progressed. The subassemblies varied from 5 to 20 tons. When the hull was ready for the main-deck installation, the slab sections were swung into place and welded. As construction progressed, the superstructure was added, and the upper decks built in the same fashion.

Gross tonnage of the original 2500-hp *Evergreen State* is 1495 tons. The length over guard is 310 ft, 2 in.; length between perpendiculars, 287 ft. The verticle clearance on the car deck is 14 ft.

Normal operating speed of the ferry boat is 15 knots. It accommodates 800 passengers, normal seating; and has space for 100 automobiles on the seven-lane deck.

Fig. 1—Operator in foreground completes the initial cut to free flange from vertical support; operator in background bevels the tapered vertical plate for welding

Fig. 2—Here is a beam just prior to welding. Base plate will be fitted in position against the beveled edge of tapered section and welded in place

Cutting Torches Build New Beams

"Split beam" construction—a recent addition to the long line of structural-steel developments—promises to bring many changes in design and fabrication techniques in the building industry.

Rebco Steel Construction Co. is one progressive firm engaged in producing "split beams" for large projects in the Niagara Falls area. Their operation is simple; yet it is so effective that as much as 35% of wide flange beam weight can now be eliminated from ceiling joists and supporting members.

Engineers first determine the size of a beam required for a particular job and send the specifications to a plant such as Rebco Construction Co. Here, metalmen change standard wide-flange beams to "split beams."

Tapering Makes the Difference

Operators first sever a section of one flange from the vertical support, or web, using cutting torches. When this step has been completed, part of the vertical plate is cut away according to blueprint specifications (Figs. 1 and 2). Cutting speeds on this job vary from 10 to 16 ipm, depending on metal thickness. This operation tapers the vertical support. The cut edge is then trimmed smooth and any remaining slag is chipped away.

The flange plate is then fitted into position against the newly cut edge of the tapered section, held snugly, and welded in place. The split beam is now complete; but before it is approved, the welds are tested for strength, porosity and penetration to assure satisfactory performance when it is incorporated in a steel structure.

Although these beams are far lighter than standard wide-flange beams, the experts claim that they have a strength equal to the heavier beams.

All signs point to split beams being widely used in the future for bridge and tower construction, as well as for canopies on new buildings (Fig. 3).

Based on a story by the Linde Co., New York, N. Y.

Fig. 3—About 35% of the structural-steel weight was eliminated from this building through use of modern split-beam construction

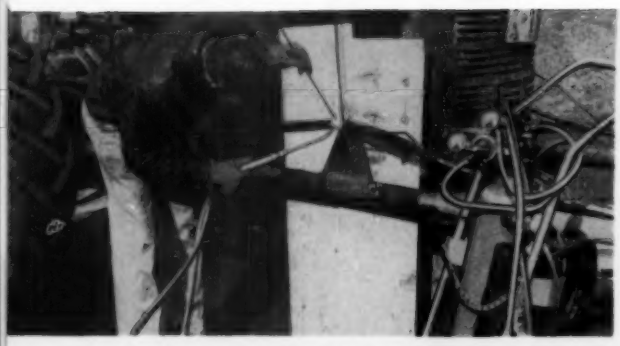


Fig. 1—Here an operator makes a repair on a cast-iron part without having to dismantle the tractor. Spark shield behind the work protects the engine

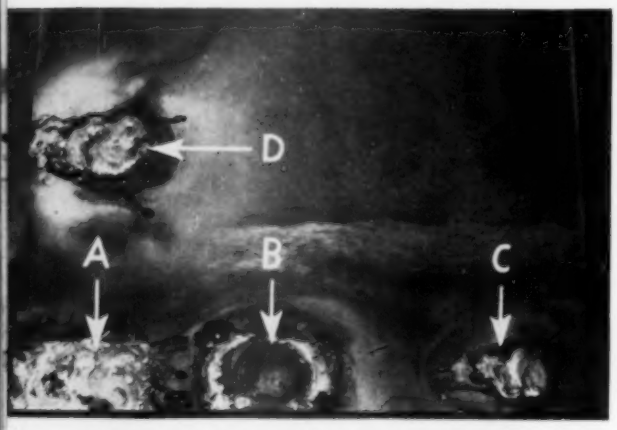


Fig. 2—Compare your work with these good and bad examples. (A) Correct tinning. (B) Too much heat. Bronze runs to edges of puddle leaving oxidized area in the center. (C) Too little heat. Bronze builds up. (D) Surface not ground. Bronze acts as if deposited on a fire brick

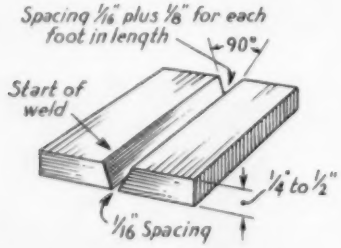


Fig. 3—This is how you should bevel the edges of a part thicker than $^1/_8$ in. if you want good results

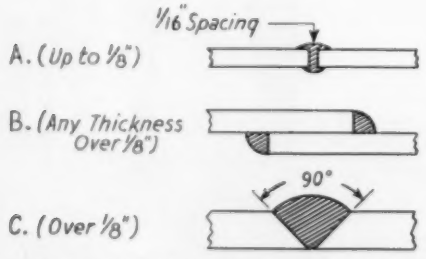


Fig. 4—This chart illustrates typical joints used in braze welding copper and brass. (A) Open-square butt joint for thicknesses up to $^1/_8$ in. (B) Lap-weld joint. (C) Single-vee butt joint

Solve Repair Problems with Braze Welding

When it comes to making low cost repairs in the shop or on the farm, many experienced welding operators choose braze welding. . .an easy way to join stee', cast iron, malleable iron and dissimilar metals.

Here are several features of braze welding that will help you see why the process is worth while. Because of the simplicity of the method, you have exact control over the temperature of the base metal and the melting rod. In addition, braze welding requires less heat than fusion welding. That is why repairs made this way are rapid; you will save time and gas on hundreds of jobs because of this feature. Also, cast iron parts—usually a headache to reclaim—can be braze welded quickly and easily because extensive heating and controlled cooling are often eliminated (Fig. 1).

Is Braze Welding the Same as Brazing?

A brazed joint is always designed so that it requires a *thin* film of filler metal, as in a sweat-type fitting. In fact, a brazed joint of this type is quite weak if the filler metal is too thick. In braze welding, on the other hand, the joint design is the same as in fusion welding. A braze-welded joint depends for strength on slight rod penetration of the base-metal surface in addition to a build-up of filler metal.

When you have a repair job that requires joining two different materials (say steel and copper), here is a good rule to remember: If the two metals can be braze welded individually, they can be braze welded together. This makes the list of braze welding applications practically endless.

Helpful Hints

You know that copper and zinc are the major ingredients in bronze rod, the rod most commonly used in braze welding. Other elements may include small amounts of tin, iron, manganese and silicon to make it free flowing, to deoxidize the weld metal and to decrease the tendency to fume. The tensile strength of a bond between a typical bronze rod and cast iron or steel averages 50,000 psi.

Facts Behind the Process

The key to successful braze welding is having molten bronze rod flow easily and evenly over the surface of a properly heated and chemically clean base metal (Fig. 2).

You have seen how water acts on glass that is not perfectly clean. It tends to separate into little balls. If the glass plate is clean, water spreads out in a thin even film. When the surface to be braze welded is properly clean, the molten rod will spread well.

Remember, the secret of good braze welding is in

Based on a story by the Linde Co., New York, N. Y.

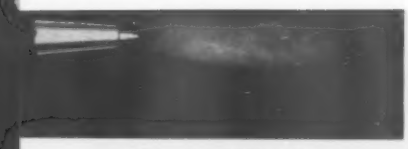


Fig. 5—(Left) This is how an excess-oxygen flame appears. The flame is small, hot and ideal for braze welds. Fig. 6—(Center) When the rim and spoke have tinned properly, hold end of the bronze welding rod against the rim. Fig. 7—(Right) After tinning the vee, the bronze welding rod is added to the break in this cast-iron part

the tinning of the joint. And good tinning is not possible if the base metal is not free of oxides. So, in addition to removing paint, dirt and grease, it is a good idea to clean off the oxide film that forms on the unprotected surface of your work. Contrary to popular belief, flux is not a cleaner and will not make up for an improperly prepared surface. For small parts, a file or sandpaper can be used; on larger pieces a stiff wire brush will do the trick.

Flux Makes Good Welds Stronger

A check on the history of the term "flux" shows that it means "to flow." And that's the exact purpose of a welding flux. . .to cause oxides, built up as the metal is heated, to flow out of the weld.

These oxides may be interesting to the high-school chemistry student, but they are just a bother to the welding operator. They build up as a coating of scum and crust on the tops of welds, preventing the rod from tinning the base metal. If these oxides are stirred into the puddle, the strength of the finished braze weld is impaired.

Remember, no single flux can be used for all metals because a flux that floats out the oxides of one metal may fail to do the same job on another.

Be sure you select the exact flux for your job before you begin work. This will save you clean-up time, and will improve results of repair job.

Braze-Welding Technique

For base metal thicker than $^1/_8$ in., the edges of joints should be beveled to provide a welding vee. To improve the efficiency of braze welding for some repair jobs, special joint designs have been developed. Check Figs. 3 and 4. Keep these on hand so you can refer to them for future jobs.

After you have selected the proper flux and thoroughly cleaned the workpiece, you are ready to begin. Light the torch and adjust the flame so that it has a slight excess of oxygen. If you are not sure of the precise adjustment for this, look at Fig. 5. Now fit the parts together and begin to heat.

Proper braze welding temperature for most metals is indicated when the base metal just begins to glow. If the operator begins applying welding rod before the base metal is hot enough, the molten rod will not flow over the surface but will form in drops. If you get the metal too hot, molten rod will tend to boil.

Here Is a Typical Job

Repairing a broken wheel is a good example of how easily braze-welded repairs can be made in steel. Steps followed here are basically the same as you would use for other metals.

When a half-dollar size area has been properly heated with the oxyacetylene flame, hold the fluxed end of the rod against the rim as shown in Fig. 6. It will melt and form a puddle about the size of a dime. Keep the rod in the puddle and move it in circles to work out air bubbles. Now simply continue adding rod and move the puddle around the spoke.

If your welding rod should stick to the puddle, do not jerk it loose. Melt it loose with the flame. The job is finished when you have circled the spoke and joined it to the rim with weld metal. Clean off the flux with a file or brush and the part is ready for service.

Broken bikes, baby carriages and many other items can be repaired by this same method.

Table 1—Recommended Rod Sizes and Drill-Tip Sizes for Various Thicknesses of Cast Iron

Thickness of cast iron, in.	Bronze rod, in.	Recommended drill-tip sizes
$^1/_4$	$^1/_8$	50–45
$^3/_8$	$^3/_{16}$	47–42
$^1/_2$	$^3/_{16}$–$^1/_4$	44–36
$^3/_4$	$^1/_4$–$^3/_8$	38–30
1	$^1/_4$–$^3/_4$	32–25
$1^1/_2$	$^3/_8$	28–22
Over $1^1/_2$	$^3/_8$	25–20

Braze Welding Cast Iron

Braze welding cast iron is a handy process for reclaiming dozens of small automobile parts for a fraction of their replacement cost.

Take a cracked gear housing, for example. Start off by veeing the crack and cleaning the surrounding area. Now tack weld each end of the part by bringing the metal to a red heat and applying a small amount of bronze rod. Then, starting at one end, tin the bottom and sides of the vee. If the metal is at the proper temperature, the bronze rod will spread in a paper-thin layer over the heated area. After this, go back and fill up the vee to the top—working carefully from one end to the other (Fig. 7). It is a good idea to reinforce this joint by adding enough filler metal to raise the weld about $^1/_{16}$ in. above the base-metal surface. Allow the piece to cool and you are in business.

Use the Right Size Tip

Table 1 shows what size tip and rod should be used for welding various thicknesses of cast iron. Smaller sizes on chart are for beginners, while larger sizes are suggested for more experienced operators.

In general, a tip one size larger than that recommended for similar thicknesses of steel should be used for welding copper and brass parts. This is because these metals are excellent conductors of heat. The heat from the torch flame tends to "run away" from the weld into the base metal.

Society News

Social Activities Round Out Fall-Meeting Program

A variety of technical and social activities are planned for the National Fall Meeting of AWS which will be held this year in Detroit, September 28th through October 1st. Supplementing the 48 technical papers to be presented during the four-day meeting is a social program for the enjoyment of members and their guests.

Highlight of the social part of the meeting is a banquet sponsored by the Detroit section. Featuring a full course dinner, door prizes, entertainment and dancing, the banquet will be held on Tuesday evening, September 29th, in the grand ballroom of the Sheraton-Cadillac Hotel. A keynote speaker will round out the program.

As part of a special ladies' program, a number of activities have been planned. Included are sightseeing tours to the Botanical Gardens at Belle Isle, historic Greenfield Village, the Fort Malden National Historic Park at Amherstburg, Ontario, and Cranbrook Institute of Science. Luncheons, entertainment and a fashion show are also planned.

On Wednesday morning, members and guests will visit the Ford Motor Co.'s Dearborn, Mich., facilities. The vast, self-contained plant on the Rouge River carries on all phases of automobile manufacture—from iron ore to finished product. The tour will include visits to the open hearth, blooming mill, rolling mill and stamping operations. It is doubtful, however, that the final assembly facilities will be open for inspection due to model changeover.

Arrangements are also being made for a plant tour of the Canadian Bridge Works of Dominion Steel and Coal Corp. in Windsor, Ont., on Thursday morning, October 1st. Structural-steel fabrication of an 1100 ton all-shop-welded hospital building, continuous deck trusses for an 886-ft, 950-ton highway bridge, simple deck trusses for a 1220-ft 4000-ton highway bridge, 80-ft railway bridge girders and a hot-dip galvanizing process for transmission lines will be seen.

Bus transportation will be provided from the hotel to and from the plants visited.

The AWS Technical Papers Committee has selected 48 papers on various phases of welding for presentation at the National Meeting. The following is a schedule of the sessions: Monday P.M.—Resistance Welding, Toughness in Steel Weldments; Tuesday A.M.—Automotive Welding, Miscellaneous Alloys; Wednesday A.M.—Nondestructive Testing, Inert-gas Welding, Welded Structures; Wednesday P.M.—Weldability of Steels, Process Development; Thursday A.M.—Aluminum, Welded Structures; Thursday P.M.—Titanium, Tantalum and Beryllium Weldments.

Everyone attending the meeting should find their particular field of interest represented among the many topics discussed.

AWS MEMBERS TO TOUR FORD PLANT

The 1½ mile long manufacturing facilities on the Rouge River in Dearborn take in iron ore and turn out completed automobiles. AWS members attending the National Fall Meeting will tour the plant on September 30th

KEEPING YOU POSTED

by Fred L. Plummer

● During the past year members of the SOCIETY approved several changes in its organization structure. The accompanying chart shows the relation of the Board of Directors, its Councils and Executive-Finance Committee and the principal standing and special committees. More than one hundred committees and subcommittees are included in Educational, Handbook and Technical Activities.

● The May 25 issue of *Barron's National Business and Financial Weekly* included an important article "Progress in Welding" which is typical of many such articles resulting from the activities of our Information Service.

● Members have received a ballot regarding simplified by-laws which were printed in the May issue of the JOURNAL. Be sure to return your ballot to headquarters prior to August 14th.

● Have you sent in your hotel reservation request for the National Fall Meeting to be held in Detroit, September 28–October 1st? Initial room confirmations will be mailed August 1st. Insure a reservation at your preferred hotel by prompt action.

● The Refinery Division of the American Petroleum Institute held a national meeting in New York during the week of May 25th. The following week, the Fifth World Petroleum Congress convened in New York with a large exposition at the Coliseum. Visitors at headquarters included A. V. Phillips of Sparling Tank of Canada, Marsh and Ulm of Graver Tank of Chicago, Curtis, who is an associate of past AWS President Sander at Consolidated Western Division of U. S. Steel in Los Angeles, several representatives of the major petroleum corporations and many friends from foreign countries, including Hirota and Kinukawa of Toyo Kanetsu in Tokyo.

● The SOCIETY installed an exhibit at the Petroleum Exposition. This was manned during the entire week by AWS staff members and by representatives of some of our major manufacturers.

● Treasurer H. E. Rockefeller and President C. I. MacGuffie spent much time at headquarters with your Secretary and Asst. Treas. Frank Mooney studying financial results for the past three years and preparing budget forecasts for the next three years. These were based on comprehensive studies made by each department head.

● Staff members entertained Bob Irving at a special luncheon at the Engineers' Club on May 29th prior to his departure to assume new responsibilities with *Iron Age* in Philadelphia.

AMERICAN WELDING SOCIETY—ORGANIZATION CHART

P President (Chairman of Board of Directors and Executive-Finance Committee)
VP Vice President (Total of three, each Chairman of one Council)
PP Past President (Total of two, one is Chairman of Administrative Council)
T Treasurer
DL Director at Large (Total of thirteen)
DD District Director (Total of eleven)

● On June 3rd, your Secretary attended technical committee meetings of NFPA at Atlantic City, returning to New York the next day after joining briefly with other society representatives at a meeting of the National Association of Exhibit Managers. Convention Manager Frank Mooney attended the two-day meetings of this group and served as chairman of its important Resolutions Committee.

● On June 8th, your Executive and Finance Committee met in the Secretary's office to prepare a final budget for the fiscal year beginning June 1, 1959, and to consider other matters on the agenda for the meeting of the Board of Directors scheduled for the following day.

● At this meeting of the Board of Directors the 1959–60 budget as recommended by the Executive and Finance Committee was approved. This provides for two additional staff members: Fred Talento who joined the staff June 25 to assist Editor Rossi in the sale of advertising space in the JOURNAL and a second who will be added to the staff to assist Technical Secretary Fenton in the preparation of recommended practices and standards.

● Members of the Board also reappointed your Secretary and Asst. Secretary Mooney for the 1959–60 administrative year, confirmed personnel recommended by President MacGuffie to serve on standing and special committees, established Adams Memorial Membership Awards to be given to outstanding educators, voted to extend an invitation to the International Institute of Welding to hold its 1961 Annual Assembly in New York in conjunction with the Annual Meeting and Welding Exposition of AWS, and authorized the appointment of a special Missiles and Rockets Welded Fabrication Committee.

● Your Secretary announced that: NWSA has decided not to join in meeting with AWS in New York in 1961; ASM has graciously changed the dates for its 1960 Southwestern Metal Congress and Exposition in Dallas to May 9–13 so as not to conflict with the April 25–29 dates for our AWS Annual Meeting and Welding Exposition in Los Angeles; active promotion of our drive for funds for the new United Engineering Center will be coordinated with new drives by the founder societies (ground-breaking ceremonies are scheduled for October 15); Public Relations Committee members and others are giving attention to a proposed law introduced in the State of Pennsylvania which would require welding of line pipe to follow a limited sequence; currently serving District Directors will continue in office under revised By-Laws as follows—Districts 1, 4, 7 and 10 until May 31, 1960, Districts 2, 5, 8 and 11 until May 31, 1961 and Districts 3, 6 and 9 until May 31, 1962.

● On June 10th, 21 men—mostly representatives of major fabricators of missiles and rockets—met at the call of Director Don Howard to explore mutual problems and decide if an AWS sponsored group might aid in resolving some of the more critical problems. Discussion disclosed a surprisingly uniform feeling that a task force, forum or committee activity would be most helpful. Such a group is now being organized as a special committee.

● On June 12th, your Secretary visited the Bayonne research laboratories of International Nickel Co. to discuss an interpretive report on the "Welding of Ductile Iron" with author G. R. Pease, head of the Welding Division, and to enjoy a tour of the laboratories.

● Vice-President R. D. Thomas, Jr., participated on June 16th in a panel discussion on "The Place of Manufacturing Process Courses in the Engineering Curriculum" at the Pittsburgh meeting of the Amer. Soc. for Engrg. Education.

● The SOCIETY suffered a grievous loss on June 16th with the sudden death of R. M. Wilson, Jr., a member of the staff of International Nickel Co. and a director and member of the Executive-Finance Committee of AWS. JOURNAL Editor Rossi and your Secretary attended the funeral in Montclair, N. J., on June 18th.

● Technical Secretary Ed Fenton and his wife flew from New York to Geneva, Switzerland, on June 19th. While in Europe he will visit headquarters of the International Standards Organization in Geneva, the French Institute of Welding in Paris and attend the Annual Assembly of the International Institute of Welding in Yugoslavia.

AWS DIRECTORS-AT-LARGE

Term Expires	1960	1961	1962
	J. F. Deffenbaugh	A. A. Holzbaur	Jay Bland
	A. E. Pearson	D. B. Howard	F. G. Singleton
	C. M. Styer	C. E. Jackson	C. B. Smith
		J. L. York	J. R. Stitt

AWS DISTRICT DIRECTORS

District No. 1•New England	G. W. Kirkley	District No. 6•Central	J. N. Alcock
District No. 2•Middle Eastern	E. E. Goehringer	District No. 7•West Central	L. L. Baugh
District No. 3•North Central	J. W. Kehoe	District No. 8•Midwest	G. O. Bland
District No. 4•Southeast	E. C. Miller	District No. 9•Southwest	C. L. Moss III
District No. 5•East Central	H. E. Schultz	District No. 10•Western	F. V. McGinley
		District No. 11•Northwest	C. B. Robinson

AWS PAST PRESIDENT DIRECTORS

J. J. Chyle G. O. Hoglund C. P. Sander

Welcome

•Supporting Companies

Effective May 1, 1959

G. S. Parsons Co.
3211 India St.
San Diego 1, Calif.

Effective July 1, 1959

Ford Motor Co.
Nashville Glass Plant
Box 1355
Nashville, Tenn.

D. W. Onan & Sons, Inc.
2515 University Ave., S. E.
Minneapolis 14, Minn.

EDUCATIONAL ACTIVITIES

Educational Symposium Scheduled

National Fall Meeting

The Educational Activities Committee has scheduled a special symposium-type conference during the week of the Fall Meeting in Detroit. The last open educational meeting was held in St. Louis during the National Spring Meeting there in 1958. Attendance at the St. Louis educational "get together" was greater than expected and many had to be turned away.

The meeting is set tentatively for Wednesday, September 29th. It will be held in the morning, followed by a luncheon, with provision made to continue the discussion in the afternoon if desirable, also, it may be possible to schedule a visit to one of the local schools where the curriculum may be studied and the layout observed.

The success of these group meetings indicates that AWS members want to take an active part in the SOCIETY's educational activities. They are eager to hear of pending projects and are anxious to learn about the techniques other sections are using. Open educational meetings are extremely valuable, since they give everyone an opportunity to discuss sectional educational problems and hear how others have treated similar situations.

All sections have been invited to send a representative to the meeting. In addition, section educational representatives have been sent invitations.

Program

A very flexible program is being arranged. Following a short opening address by President C. I. MacGuffie, the education committee chairmen will give reports, discuss projects and define future objectives. Questions from the floor will be welcome.

R. D. Thomas, Jr., vice-president of the SOCIETY and a strong advocate for improved education, will also give a brief talk. He will pay particular attention to the needs of the sections.

There will be only a few speakers, but it is expected that each will contribute something that can be used by the sections to improve their educational program. The talks will be limited in time so that there may be ample opportunity for discussion.

The discussion period, if it follows the pattern set at St. Louis, may prove to be the most rewarding part of the meeting. Problems facing many sections today have already been solved by other sections. A free exchange of such experiences should be of benefit to many.

The meeting provides an opportunity for a direct report to the membership by the Educational Committees. The membership, in turn, has a chance to discuss with EAC various educational projects. By this means, projects can be improved or modified to meet the needs of the majority. Certain areas of the country require specialized information and educational programs must be slanted to specific fields.

Welding Education

Welding education should be the concern of the entire industry. It is of vital importance, however, to members of the AMERICAN WELDING SOCIETY. Experience shows that when educational courses are arranged by local sections, they are usually very well attended. This fact would also indicate that if there were more courses on welding, more people would attend. The WELDING JOURNAL, June 1959 reports, "An impressive gathering of over 275 men was on hand Tuesday night, March 17th, for the second session of a course on 'Fundamentals of Arc Welding'. . .this series of lectures. . .has created a great deal of interest in the industrial Mahoning Valley area."

This is but one example of the demand for welding knowledge. The experience is duplicated in many other parts of the country. Some AWS Sections may be handicapped by lack of experience in promoting such courses. A number of sections have been particularly successful and their advice should be exceedingly valuable.

If each section will assign one of its members to attend the Wednesday Educational Conference at Detroit, the result will be reflected in the increased amount of welding education available throughout the nation.

April is National Welded Products Month—let 1959–60 be *Welding Education Year.*

Conference on the Fracture of Engineering Materials

The Eastern New York Chapter of the American Society for Metals will sponsor a conference on the Fracture of Engineering Materials to be held August 23rd, 24th and 25th on the RPI campus, Troy, N.Y. There has been considerable activity recently in the study of fracture as a problem in metal physics. An international seminar on the Atomic Mechanisms of Fracture, Apr. 12–14, 1959, at Swampscott, Mass., attests to the increasing interest in this problem. While the understanding of fracture mechanisms is currently receiving great emphasis, the translation of the present state of the knowledge for the practicing engineer is no less important. The August conference will review the current status of the fracture problem as it relates to materials of interest to the metallurgical, materials and mechanical engineer.

A tentative program for this conference has been prepared to include topics of major interest. National authorities who are working in these selected fields (including W. A. Backofen, R. Davis, M. Gensamer, R. W. Guard, G. Irwin, J. R. Low, M. J. Manjoine, G. Sinclair and R. D. Stout) have agreed to present these reviews which will be published in a bound volume which will be available to registrants at a reduced cost. Abstracts will be distributed at the conference.

A conference fee of $10 will be charged to cover costs. Rensselaer Polytechnic Institute has offered on-campus dining services and overnight accommodations to conference attendees.

California

000 of this one type of tube per

dinner and dancing. There were

SECTION NEWS AND EVENTS

As Reported to Catherine M. O'Leary

Two New Sections Formed by AWS; One Reactivated

The formation of two new sections, one in San Diego, Calif., and the other in Mobile, Ala., was recently authorized by the board of directors of AWS. A third group, the Eastern Illinois Section, was reactivated.

SAN DIEGO SECTION

Boasting a charter membership of 89, the *San Diego* Section of AWS was voted into legal existence by the national board of directors in Chicago in April of this year.

Robert L. Hawkins, the first chairman of the new section, cited the high concentration of aircraft, missile and electronic industries, and the new welding techniques used by these industries as factors making such a group vital in the San Diego area. He said that one function of the group would be to stimulate knowledge of the art and science of welding among interested young people of the community and to make speakers, slides and films available for this purpose.

Other officers of the San Diego Section are: 1st Vice-Chairman, Robert Fullerton, Ryan Aeronautical; 2nd Vice-Chairman, Donald A. Provancher, Rohr Aircraft Corp.; Program Chairman, Roger Beemer, Solar Aircraft; Program Vice-Chairman, Dell Hughes, Liquid Carbonic; Membership Chairman, Herb Maynard, Victor Equipment; Membership Vice-Chairman, Lewis Gray, Bailey Equipment Co.; Recording Secretary, Daniel E. Arndt, Rohr Aircraft Corp.; Recording Vice-Secretary, Robert Manary, Rohr Aircraft Corp.; Treasurer, Wells Perry McGregor, Convair Astronautics. Executive Committee members are: Frank Harkins, Solar Aircraft; Seth Jenkins, Rohr Aircraft; Edmund Bailey, Bailey Equipment Co.; Kenneth Adams, Convair; Jack Maloney, Rohr Aircraft; Barney Le Blanc, National Steel Shipbldg.; and Lee Leach, Ryan Aeronautical. Also, Ways & Means, W. J. Phillips, Convair; Sergeant-at-Arms, C. P. Davis, Solar Aircraft; Entertainment, Royal Carthcart, National Cylinder Gas; Virgil Lewis, Parson Co.; Education Activity Chairman, Floyd C. Nelson, Solar Aircraft; Codes Chairman, Albert Schwab, California Aircraft; Publicity Chairman, Howard Schwitkis, Rohr Aircraft.

MOBILE SECTION

On Apr. 9, 1959, the board of directors of the AMERICAN WELDING SOCIETY authorized the formation of Alabama's *Mobile* Section, bringing the number of active sections to 84. The new section, which has 50 charter members, is headed by Leo D. Veal, Chairman, and Earl W. Parham, Secretary.

AWS Director Ed C. Miller was one of those who played an important role in laying the groundwork for section activation.

EASTERN ILLINOIS SECTION

Reorganization of the *Eastern Illinois* Section of the AMERICAN WELDING SOCIETY became effective on Feb. 1, 1959, after the group was inactive for about two years. Membership is now at 36 and the newly elected officers are: Chairman, Ralph Ross, Hyster Co.; 1st Vice-Chairman, Elmer Norris, Berkeley Co.; 2nd Vice-Chairman, George Maney, Food, Machine and Chemical Corp.; Secretary, Herbert F. Depke, Depke Welding Supplies; Treasurer, Everett Morris, Electric Steel Foundry Co. Members-at-Large are: Bud Raymong, Bud's Metal Shop; Ed Bernardi, W. M. Hales Co.; Raymond Francis, Robert Francis, Robert Holmes and Brothers, Inc.

SAN DIEGO SECTION ORGANIZED

AWS National President G. O. Hoglund looks on as Secretary Fred Plummer (center) accepts applications of charter members of the San Diego Section from Robert L. Hawkins, chairman of the new section at 40th Annual Meeting in Chicago

ATTENTION SECTION SECRETARIES:

Notices for November 1959 meetings must reach JOURNAL office prior to August 20th so that they may be published in the October Section Meeting Calendar. Give full information concerning time, place, topic and speaker for each meeting.

California

GUIDED TOUR

Fontana—Approximately 250 members and guests from the *Los Angeles* and *Long Beach* Sections enjoyed a dinner and tour of the Kaiser Steel Corp.'s plant facilities at Fontana on May 21, 1959.

All arrangements for the tour were made by and under the direction of Chas. Zwissler, a director of the Los Angeles Section and a welding engineer for Kaiser Steel, Fabrication Division, in Los Angeles.

A bus was provided by the Long Beach Section for transportation of members of both Sections residing in the Long Beach area.

Upon arrival at the Kaiser Steel plant, members and guests were met by Al Lynch, assistant director of public relations at the Fontana facility, and directed to the cafeteria where dinner was served. There Paul Anderson, in charge of guides for the tour, gave a welcoming address and then introduced John Ross, chairman of the Los Angeles Section. Mr. Ross gave a brief talk covering the history and background of the Kaiser company, and told how he became acquainted with the organization during the construction of the Boulder Dam in the lean years of 1934–35.

Following the dinner, the members and guests convened in small groups and were assigned competent guides by Mr. Anderson. Some of the items observed during the tour were as follows: the newly installed oxygen furnaces, soaking pits, pipe mills, coke ovens and blooming mills. The tour consumed approximately two hours' time and was well enjoyed by all those fortunate enough to be able to participate.

PLANT TOUR

San Carlos—A very interesting tour of Eitel McCullough, transmission-tube manufacturer and electronics firm, was sponsored by the *Santa Clara Valley* Section on Tuesday evening, May 26th at 8:00 P.M. It was attended by over 80 members, wives and friends.

A briefing was given by personnel of Eitel McCullough to the entire group prior to the tour. This included general information about the plant and layout, a history of the parent company, and a history about the new plant.

The highlight of the tour was observing the manufacture of the high-power transmission tube "Klystron," including research work. Manufacture exceeds 15,000 of this one type of tube per month.

Mr. McCullough received a Navy award for the development of the "Klystron" tube during World War II.

Manufacture and facilities included in the tour were the machine shop, brazing applications, low vapor press material and "clean" room for finishing.

The tour was well arranged and conducted by Eitel McCullough personnel.

Connecticut

PLANT VISIT

Bridgeport—On May 21st, the members of the *Bridgeport* Section visited the R. A. Lalli plant. R. H. Lalli, proprietor, and chairman-elect of the Section, acted as host.

The production in this plant consists of stretch-forming the skins for helicopters. The principal materials used are aluminum, magnesium and zirconium.

The tour was followed by a dinner at the Candlelite Restaurant. Here, outgoing Chairman J. Barker was presented with a past-chairman's pin. Also, the new officers for the 1959–60 fiscal year were introduced.

An open discussion of the program and membership for next year rounded out the evening's program.

ANNUAL MEETING

New London—The annual meeting and dinner-dance of the *Hartford* Section were held Friday, May 22nd, at the Nautilus Room, Ocean Beach, New London.

Seventy-five members and guests enjoyed an excellent cocktail party, dinner and dancing. There were corsages for the ladies and door prizes.

T. A. Risch, past Section chairman, conducted the election of officers for the coming year. Those elected were as follows: Chairman, W. A. Duncklee, Chas. Pfizer Co.; Vice-Chairman, V. J. Zdon, Zane Weldcraft Supplies, Inc.; Treasurer, R. W. Anderson, Arcos Corp.; Secretary, L. B. Driscoll, Air Reduction Co.

Mr. Duncklee's first act was to award the past chairman's pin to G. W. Kirkley, outgoing chairman, who did a fine job for the Section. Mr. Kirkley has been elected director of District No. 1, an area which encompasses all of New England.

Florida

ANNUAL MEETING

Miami—The Annual Meeting of the *South Florida* Section was held on May 20th, at the Miami Pioneers Club and was attended by 75 members and guests.

After installation of new officers, Tom Shirley of the Fish and Wild Life Department of the State of Florida, showed movies of conservation efforts which have appeared on nationally televised programs. The films, "You Asked for It" and "Bold Journey," were well received.

Everyone enjoyed the buffet supper which finally ended at 10:30 P.M.

Indiana

WELDING SAFETY

Indianapolis—The final meeting

VISITED BY LOS ANGELES AND LONG BEACH SECTIONS

Some 250 members of the Los Angeles and Long Beach Sections visited the plant facilities of the Kaiser Steel Corp. at Fontana, Calif., on May 21st

of the *Indiana* Section for the season was held on Friday, May 22nd, at McClarney's Restaurant. Thirty members and guests were served dinner at 6:30 P.M.

A short business meeting was held immediately following the dinner. The following officers were announced for the 1959–60 year: Robert Hilburt, chairman; Byron Canine, 1st vice-chairman; Frank Stout, 2nd vice-chairman; Fred Watts, treasurer; Mrs. Geneva Mahan, secretary. The following members were elected to the executive committee: Edman Holt, Roy Martin, Wm. Morgan, Carl Osterhous, Robert Roth, Michael Schaeffer, Everett Smith and Douglas Fitting.

Harold Schultz, District No. 5 director, presented a trophy to the Indiana Section for the largest membership increase during the year.

A. N. (Art) Kugler, chief welding engineer of the Technical Division Department of the Air Reduction Co., gave a very interesting talk on "Welding Safety." Mr. Kugler, a graduate of Stevens Institute of Technology, accompanied his talk with two flip slides; one on safety in the use of the oxyacetylene flame and the other on safety in arc welding and cutting. Mr. Kugler added to his presentation by relating various cases and incidents that he had been consulted on during his many years in the welding industry.

Special guests for the evening, besides Mr. Schultz, were Mrs. Schultz and Mrs. Mahan.

ANNUAL MEETING

South Bend—The *Michiana* Section finished its 15th season of meetings with the annual business and social meeting on Thursday, May 21st. Announcement of election of officers for the 1959–60 season was made as follows: Chairman, Robert Hess, Mittler Supply Co.; Vice-Chairman, Robert Bauss, Michiana Welding Supply Co.; Secretary, W. G. Fassnacht, Bendix Products; Treasurer, Leo Cuthbert, Whirlpool Corp.; Executive Committee—Robert Schrader, Virgil Young, Woodrow Koehler, Floyd Doolittle, Everett Lyerla, J. A. Miller and John Weis.

A discussion of ways and means to augment the pamphlet, "Opportunities in the Welding Industry," published by the Educational Activities Committee, brought forth several ideas for the new officers to consider. A gratifying amount of interest in helping high-school welding instructors was expressed.

The meeting closed with three films: one produced by the U. S. Dept. of Agriculture, showing the effects of poor soil management in the Mississippi River Valley and how to reclaim the land; and two concerning recreational facilities in the Waterton National Park and God's Lake areas in Canada.

PAST CHAIRMEN HONORED BY KANSAS CITY SECTION

Chairman-elect Jim Warn presents plaque to J. A. Hall, first chairman of the Kansas City Section, in appreciation of the leadership provided by the past chairmen

Among the past chairmen present at the May 14th meeting of the Kansas City Section were (left to right): E. H. Finlay (1943–44), A. C. Sluss (1945–46), L. N. Williams (1946–47), J. M. Payne (1952–53), Mr. Hall (1937–38), J. L. Frizzel (1938–40), D. D. DeBrunner (1944–45), A. G. Hedstrom (1953–54), F. G. Singleton (1956–57) and B. Harrington (1957–58)

The new officers elected for the 1959–60 fiscal year are (left to right): C. J. Sise, treasurer; C. Reardon, director; Mr. Warn; L. L. Thompson, secretary; and W. Spencer, vice-chairman

After-dinner speaker for the evening was Wallace Good who talked on the principles and operations of a Science Field Club

Missouri

PAST-CHAIRMEN NIGHT

Kansas City—All past chairmen of the *Kansas City* Section from its origin in 1937 through the present time were invited to the May dinner meeting held in the World War Memorial Building on May 14th. The Section heartily recommends this type of program as it brings together those who have assisted the younger members over the years in developing different techniques in welding.

After-dinner speaker was Wallace Good, science teacher at Wyandotte High School, Kansas City, Kan., who spoke on the principles and operations of a Science Field Club which is intended to prepare high-school students for professional careers in physics, chemical engineering, metallurgy and other scientific fields.

New Jersey

JOURNAL PUBLICATION

Newark—The *New Jersey* Section changed its pace for the last meeting of the season on May 19th and learned about some of the problems of its own national organization. B. E. Rossi, editor of the WELDING JOURNAL, discussed the many details that are involved in producing such a comprehensive technical publication. He reviewed the background, growth and policies over the long period from the JOURNAL's inception, pointing out, among other things, how William Spraragen guided the JOURNAL's course for 32 years.

Mr. Rossi noted that the JOURNAL is read by diverse technical and management people such as engineers, metallurgists, company executives, supervisors, craftsmen, etc., and that its circulation reaches most foreign countries. He also explained how the editorial content of the book is divided to fulfill the needs and interests of the various groups within the SOCIETY: the Feature Section, Practical Welder and Designer Section, News Sections, Special Features and Research Supplement.

The many steps in the processing of a technical article were outlined by the speaker, disclosing the extreme care and attention given to each contribution. No trade names, subtle advertising, etc., are allowed. Also, original publication rights constitute another requirement for Feature and Supplement papers.

Worth-while comments were made during the discussion period that followed, and Mr. Rossi brought out that the JOURNAL staff was always interested in the members' reactions and ideas. He did note, however, that manpower and budget limits do exist, thereby plac-

NEW JERSEY SECTION HEARS TALK ON WELDING JOURNAL

Seated at speaker's table at the May 19th meeting of New Jersey Section were (left to right): R. Thornton, H. Hoffman, Section Chairman Bill Benz, Welding Journal Editor B. E. Rossi, Program Chairman G. R. Pease, National Secretary F. L. Plummer, President C. I. MacGuffie and M. Sheely

The principal speaker of the evening was "Bonney" Rossi. He gave an inside view of the many details involved in the publication of such a comprehensive technical magazine as the Welding Journal

Part of the large crowd present at the dinner that preceded the meeting

The newly elected Section officers for the 1959-60 fiscal year are (left to right): S. Sullivan, treasurer; Mr. Thornton, vice-chairman; Mr. Hoffman, chairman; and E. F. Bowden, secretary

WELDING-ENGINEERING TRAINING DISCUSSED BY McCAULEY

The importance of welding-engineering training to the entire industry was discussed at length by Roy B. McCauley at the April 23rd meeting of the Long Island Section. He is shown (above, second from right) receiving speaker's gift from E. Moles, while Jerry Crowley (left) and Bill Rogers look on

Cub Scout E. Tomlinson of Pack 181 Wantagh and Explorer Scout N. Inman of Troop 150 Lynbrook deliver a new 49-star flag to Charles Henne, chairman of Long Island Section. The Scouts are part of the Nassau County Council's "Pride in Old Glory" campaign; they are selling flags to individuals and organizations as a patriotic service

ing definite limitations on what can be done.

Before Mr. Rossi spoke, the new officers were introduced as follows: Chairman, H. L. Hoffman; Vice-Chairman, R. V. Thornton; Secretary, E. F. Bowden; and Treasurer, S. L. Sullivan.

The members also had an opportunity to hear from National Secretary F. L. Plummer and President C. I. MacGuffie.

New York

WELDING EDUCATION

Hicksville—The *Long Island* Section was honored by the presence of Roy B. McCauley as principal speaker at their April meeting held at Henningsen's Restaurant on April 23rd. Professor McCauley is Chairman of the Welding Engineering Department at Ohio State University. His reputation as a teacher in welding is synonymous with Ohio State's leadership in the education of welding engineers.

Professor McCauley based his talk on the fundamental need in industry for properly trained welding engineers. He outlined, in detail, what is being done at Ohio State to meet this need.

NEW OFFICERS

New York—The *New York* Section announces the election of the following officers and committee chairmen for the 1959–60 season: Chairman, Harry D. Landis, Jr., Armco International Corp.; 1st Vice-Chairman, M. D. Bellware, International Nickel Co., Inc.; 2nd Vice-Chairman, E. N. Madison, Prest-O-Sales & Service Inc.; Secretary, M. A. Feiner, P. Feiner & Sons Inc.; Treasurer, Anders V. Thoren, Travelers Insurance Co.; Program Committee, Don C. Herrschaft, Handy & Harman; Membership Committee, C. M. Dick, Metal & Thermit Corp.; Publicity Committee, Harry C. Cook, Esso Research & Eng. Co.; Year Book Committee, D. Buley, International Nickel Co. Inc.; Smoker Committee, J. W. Stewart, Whitehead Metals Inc.; Arrangements committee, M. J. Giraldi, Construction Eng. Corp.; and Technical Rep. & Education, J. L. Cahill, New York Naval Shipyard.

These members are assembling together a series of outstanding speakers who will provide interesting and informative talks for the coming season. They are expanding every effort to make 1959–60 a banner season for the New York Section in both attendance and enthusiasm.

STUDENT AWARDS

New York—The *New York* Section recently presented the first awards in what is expected to become an annual program. The awards went to students at the Polytechnic Institute of Brooklyn for papers on welding. The New York Section established the award program in order to promote interest in welding among college students in the area.

STUDENTS RECEIVE AWARDS FROM NEW YORK SECTION

Awards were presented at the June 8th meeting of the New York Section to the two students at the Polytechnic Institute of Brooklyn who turned in the best papers on welding during the past school year. Sam Friedman is shown accepting first prize of $200 from Dan Bellware, 1st vice-chairman. Looking on at left are Ed Madison, 2nd vice-chairman and Professor George Fischer who represented the Brooklyn Poly. On the right are Finn Haaskjold, who received the second prize of $100, and Andy Thoren, Section treasurer

The first award of two hundred dollars went to Sam Friedman for his paper "Welding of Zirconium." Mr. Friedman was graduated Summa cum Laude with the degree of Bachelor of Metallurgical Engineering. He has since taken a position with Curtiss Wright, Wood Ridge, N. J.

The second award of one hundred dollars went to Finn Haaskjold for his paper "Hot Cracking." Mr. Haaskjold was also graduated in June, with a Bachelor of Mechanical Engineering degree. He has accepted a position with the Worthington Corp., Harrison, N. J.

The awards were presented during a luncheon at Massoletti's Restaurant on June 8th, given in honor of the recipients and the judges—Professors George Fischer and Otto Henry of the Polytechnic Institute of Brooklyn.

FREIGHT-CAR FABRICATION

Olean, N. Y.—A second meeting of the *Olean-Bradford* Section was held in May to replace the one canceled in January. It took place at the Castle Restaurant in Olean on May 26th. A delicious ham dinner was served to 24 members and guests. Following the dinner, it was announced that the speaker of the evening, Bill Schuster, had been unable to keep his engagement due to a sudden change in his schedule.

James Cameron of the Berwick, Pa., Welding Research Laboratory, and John Kolnik of the New York office of American Car and Foundry, were introduced as "pinch-hitters" for Mr. Schuster. Armed with an excellent set of 3-D slides showing the progressive assembly of a hopper car, these gentlemen presented a most informative talk on the high-speed welding of freight cars. Of particular interest was the improvement in processing and fixturing which had resulted in the use of very high speeds in automatic welding in the St. Louis as well as in the Berwick plant.

North Carolina

ANNUAL MEETING

Raleigh—Election of officers of the *Carolina* Section for the coming year were announced at the May 25th meeting held at Dob's Restaurant, with the following results: Chairman, T. Jenkins, Dillon Supply Co.; 1st Vice-Chairman, H. Owen, Reco Tank Co.; 2nd Vice-Chairman, J. Martin, National Welders Supply; Treasurer, H. White, Hartford Steam Boiler Insp. & Ins. Co.; Secretary, R. Cope, North Carolina State College; and Executive Committee — O. K. Barnes and R. Gussow.

Mr. Jenkins announced that an executive committee meeting will be held the first Monday in August to formulate a program for the coming year.

A safety film on welding produced by Airco, entitled "The Guy Behind Your Back," was shown. The film pointed out the essential precautionary steps that should be taken to prevent serious accidents; the mistakes that are made and the resulting difficulties were shown.

QUIZ WINNER

Quiz program winner at the May 10th meeting of Dayton Section was Glyn Williams. He is shown (above, at left) receiving prize from Quiz Chairman Bob Hous

Ohio

ANNUAL QUIZ

Dayton—Sixty members and guests enjoyed a chicken dinner prior to the *Dayton* Section's Annual Quiz Program held at Kuntz' Cafe on Tuesday, May 10th.

The quiz was divided into the following welding classifications: Gas, Resistance, Arc and Inert Gas. A panel of experts consisting of Robert Bowman, Wright-Patterson Air Force Base; Howard Cary, Hobart Technical School; Bob Hous, Inland Manufacturing; Bill Kolb, Delco Products; and Fred Schuemeister, Air Reduction Sales, prepared the questions.

A transistor radio, the grand prize for the most points in all classifications, went to Glyn Williams who broke a four-way tie by drawing the lucky number. Charlie Adams, high man in Gas Welding, and John Blankenbuehler, high man in Arc Welding, carried out the two beverage coolers. Milton Deets and Charlie Brown took home lawn chairs for their high points in Resistance and Inert Arc.

Door prizes were drawn by Dick Stratton, Earl Garber and Don Aughe.

POWER SOURCES

Warren—As a climax of the 1958–59 season, the *Mahoning Valley* Section was very pleased to have Director-at-Large John H. Blankenbuehler give an excellent talk on "Power Sources for Arc Welding" at the May 21st meeting held at El Rio Restaurant.

The beautiful spring weather held the attendance down to 35 members and guests, but these were treated to a fine presentation to close out the year's activities.

The Section was also fortunate in obtaining P. R. Mallory's movie on the Indianapolis 500-mile race of 1958. This was shown prior to the formal meeting and was thoroughly enjoyed during the coffee hour.

Mr. Blankenbuehler's discussion, accompanied by slides, covered various characteristics of power sources such as weight, size, efficiency, portability, noise, current range adaptability (both with electrodes and mechanically) for constant current types. An interesting chart was presented showing comparisons between transformers, rectifiers and motor-generator sets with respect to volume, power factor, no load input, weight, percent maximum output, safety, electrode variety and arc blow, to mention a few.

Also discussed was the percent current drop in these various sources when the line voltage drops 10%. The motor-generator set was shown to be the most practical unit in this case, with a drop of only 1% in current with a drop of 10% in line voltage.

Constant-potential sources were also covered with respect to arc voltage, current and wire feed speeds.

At the close of the technical program, a movie was shown on the mining operations by Hobart near Vero Beach, Fla., to obtain various minerals used in the production of arc-welding electrodes.

Oregon

TUNGSTEN-ARC CUTTING

Portland—The *Portland* Section's last meeting of the season was held at the New Heathman Hotel on March 12th. The annual election of officers was held with the following results: Chairman, Geo.

SPEAKS ON TUNGSTEN-ARC CUTTING OF STAINLESS STEELS

Some of the officers and guests seated at head table at May 12th meeting of Portland Section were (left to right): Chairman-elect G. Siegner, Guest Speaker G. Conner, Chairman O. Focht and Secretary-elect E. Angell

Mr. Conner's topic dealt with the tungsten-arc cutting of austenitic stainless steels

Siegner; Vice-Chairman, Harry Swan; Secretary, E. Angell; and Treasurer, Don Rowan.

The speaker of the evening was George Conner, a welding engineer with General Electric Co., Hanford, Wash. His subject of "Tungsten-Arc Cutting of Austenitic Stainless Steels" was unusually interesting and informative, particularly because of the stainless steel uses which G.E. has at their Atomic Energy Commission's Hanford works.

Pennsylvania

PLANT VISIT

Bradford—A joint meeting of the *Olean-Bradford* Section and the local ASME Chapter was held on Tuesday, May 19th. Approximately 100 members and guests of both societies enjoyed dinner at the Emery Hotel and then proceeded to the new Electronic Components plant of the Corning Glass Works on the outskirts of the city.

W. A. Ende, plant manager of the Bradford facility, greeted the members and guests upon their arrival and explained that certain developments and inventions by the Corning Glass Works in the field of electronics made it almost mandatory for them to engage in the manufacture of these components. The large group was then broken up into smaller units and guided through the plant to witness the complete processes involved in the production of capacitors, resistors and printed circuitry boards.

High praise is due John Spiegler, chief engineer, Components plant, and his committee for the efficient manner in which the tour was conducted. Thanks are also extended to the management of the Components plant.

ANNUAL DINNER-DANCE

Philadelphia—The *Philadelphia* Section owes a vote of thanks to Don Mockus, Arcos Corp., for having arranged a highly successful dinner-dance at the Germantown Cricket Club on Saturday, May 23.

The dinner dance is an annual affair of the Philadelphia Section, traditionally symbolic of the end of another season.

Two hundred and fifty-four guests attended, enjoying the pleasurable atmosphere and surroundings afforded by the Germantown Cricket Club.

Joe Gerini and his wife were the lucky winners of the No. 1 door prize, a portable television set.

Carl Schaub, on completion of a very successful year as chairman, presented the gavel to Frank Iapalucci, his successor.

Rhode Island

MONTHLY MEETING

Providence—On May 20th the *Providence* Section met at Johnsons' Hummocks for its monthly meeting. At the completion of the dinner, the meeting was called to order by Everett Brunnckow, 1st vice-chairman. Arthur Laurenson, speaking for the Committee of Tellers, informed the chairman of the election of officers for the coming year, as follows: Chairman, Everett Brunnckow; 1st Vice-Chairman, Avery Seaman; 2nd Vice-Chairman, Stephan Hahn; Secretary, George Blome; Treasurer, W. Allen Smith, and Directors-at-Large—James T. Salomon and Cly Downing.

Guest speaker of the evening was H. A. (Butch) Sosnin of Tube Turns. His talk was on the "Qualification and Certification of Welding Procedures and Welding Operators." He spoke of the importance of first qualifying the procedure to reach a specific end result. When

DINNER-DANCE HELD BY PHILADELPHIA SECTION

This merry group reflects the atmosphere of the entire attendance at the Philadelphia Section Annual Dinner-Dance held on May 23rd

FAMILY NIGHT HELD BY NORTH TEXAS SECTION

A fine buffet-style dinner was enjoyed by everyone at the May 12th Family-night meeting of the North Texas Section

Mr. Harris, mentalist, entertained members and their wives

the procedure was established, tried and tested, the next step was to qualify the operator. Several methods of testing were mentioned and discussed. Mr. Sosnin's talk was very well received and an interesting discussion period followed.

Texas

FAMILY NIGHT

Dallas—Tuesday, May 12th, was Family Night for the *North Texas* Section. Thirty-six members and their wives gathered at Western Hills Inn for an excellent buffet-style dinner.

The featured entertainment for the evening was Mr. Harris, mentalist, who astounded everyone with his demonstrations of thought transference. All who attended enjoyed the meeting. The luckier members of the group added to their pleasure by carrying home door prizes.

PLANT TOURS

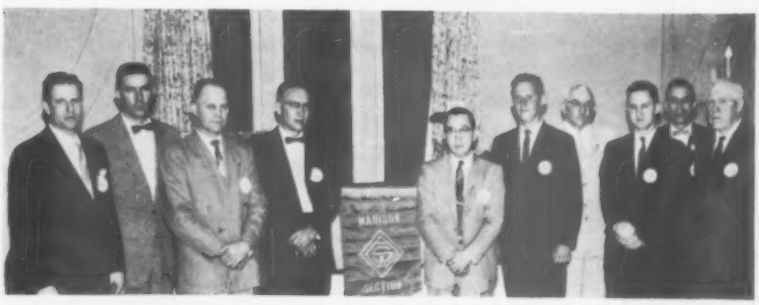
San Antonio—The *San Antonio* Section recently enjoyed two plant visits. On May 16th, 74 members traveled to Houston as guests of Sheffield Steel Division, Armco Steel Corp. Upon arriving in Houston, Sheffield arranged a barbecue dinner prior to going on the plant tour. At the plant, the plate, bar and wire mill operations were observed.

On June 1st, 71 members and guests toured the Pak-Mor Manufacturing Co. located in San Antonio.

Pak-Mor manufactures compaction-type refuse collector bodies and trailers that are in use all over the world. One of the many interesting operations on the tour was the welding jigs. These jigs, up to 30-ft long, were made in such a manner that all shrinkage and distortion was controlled so that no straightening was required.

After the plant visit a steak dinner was served at Capt. Jim's Cafe and a short business meeting followed.

NEW OFFICERS INSTALLED BY MADISON SECTION



The Madison Section announced the new officers for the 1959–60 fiscal year at its annual social meeting on May 2nd. Left to right are Secretary F. Theiler; M. Vivian, 1st Vice-Chairman; C. Fenske; C. Seitz; Chairman N. Braton; Treasurer C. Miller; and C. Druetzler, R. Graves, H. Rosenow and C. Peters

Wisconsin

ANNUAL MEETING

Madison—The *Madison* Section held its annual social and final meeting of the year at the Beloit Country Club in Beloit, Wis., on Saturday evening, May 2nd. Ninety-two persons were present at this gala affair. The evening got off to a good start with a 5:00 P.M. cocktail party followed by a 6:30 banquet. At this banquet, the 1959–60 officers were announced as follows: Chairman, Norman Braton, University of Wisconsin; 1st Vice-Chairman, Charles Fenske, Beloit Iron Works; 2nd Vice-Chairman, Jim Lauridsen, Hyland Hall Heating; Secretary, Fred Theiler, Vocational School of Madison; Treasurer, Charles Miller, Oscar Mayer Packing Co.; and Executive Members-at-Large—Charles Druetzler, Robert Graves, Charles Peters, Howard Rosenow, Merrill Vivian and Ray Knudtson.

The program for the evening was of the variety type, with a floor show and dancing. A corsage was presented to each lady and prizes, which included golf carts, camping equipment, etc., were presented at half hour intervals throughout the evening. The party ended at 1:00 A.M.

SUPPORT YOUR SOCIETY!
BE ACTIVE!

New Members

EFFECTIVE JUNE 1, 1959

MEMBERSHIP CLASSIFICATION

A—Sustaining Member
B—Member
C—Associate Member
D—Student Member
E—Honorary Member
F—Life Members

TOTAL NATIONAL MEMBERSHIP

Sustaining Members	195
Members	6,169
Associate Members	5,661
Students	222
Honorary Members	10
Life Members	15
Total	12,272

AWS Builds Men of Welding

ALBUQUERQUE

O'Neal, Vernon Lester (C)

BATON ROUGE

Andries, Luke (B)

BIRMINGHAM

Kirkpatrick, Bruce M. (B)

BOSTON

Cushing, Peter W. (C)
Delaire, Raymond J. (C)
Grant, David C. (C)
Pike, John (C)
Quigley, William S. (B)

CANADA

Mitchell, Archie (C)
Ohler, R. G. (B)

CAROLINA

Carr, Willie Paul (B)
Dedrick, George A. (B)

CHICAGO

Aspel, James A. (B)
Axberg, Milton (B)
Azola, Joseph R. (C)
Burke, Thomas E. (B)
Bushnell, Warren B. (C)
Iwaskiewicz, Joseph (C)
Philips, David P. (B)
Zegers, Vernon R. (C)

CINCINNATI

Masler, William F., Jr. (B)

CLEVELAND

Allen, E. C. (B)
Patucek, Raymond G. (C)

COLUMBUS

Kowalski, Edward M. (D)
Schmarr, Virgil A. (C)

DETROIT

Bull, Arthur W. (B)
Opel, John W. (B)
Scherer, John J. (B)

FOX VALLEY

Barteau, Gordon C. (C)
Brazones, G. E. (B)
Hiedke, Harvey E. (C)
Kalmerton, Lowell (B)

HARTFORD

Tierney, James M. (B)

HOUSTON

Bartram, John L. (B)
Conner, S. H. (B)
Ferguson, T. A. (B)

J. A. K.

Perino, Charles D., Jr. (B)

LONG ISLAND

Hallock, Fred A. (B)

LOS ANGELES

Lehner, Kenneth A. (C)
Vandaveer, Kenneth E. (C)

MAHONING VALLEY

Brandt, Harry M. (B)
Kovacs, Louis (B)
O'Hare, F. Robert (B)
Rider, Philip R. N. (C)

MARYLAND

Reagan, Penrose W. (C)

MILWAUKEE

De Alva, Guillermo Martinez (B)
Spencer, Lester F. (B)

MOBILE

Eilers, Leo F. (B)
Harrison, W. H., Jr. (B)
Hogan, Mark E. (B)
Post, Richard M. (B)

NASHVILLE

Brooks, M. S. (B)

NEW JERSEY

De Nike, Frank (B)
Swisher, James W. (B)

NEW YORK

Gerbosi, Peter F. (C)
Kald, Lembit (B)
Lare, William L. (C)
Linton, Eric J. (B)
Morrison, William S., Jr. (B)
Murray, Thomas E. (C)
Nigro, Michael F. (C)
Velapoldi, Frank M. (C)

NIAGARA FRONTIER

Campbell, John H. (C)

NORTH TEXAS

Davis, James E. (B)

NORTHWEST

Berglund, Clayton (C)
Imer, O. W. (C)
Svec, Harry R. (B)

NORTHWESTERN PA.

Cobb, Harold E. (C)
Legters, George R. (C)
Pokosh, Basil (C)
Stroup, Paul B. (C)
Yost, Harold L. (B)

OKLAHOMA CITY

Davenport, Carmen (C)

PEORIA

Cheneler, Rocco (C)
Cortright, Louis J. (B)
Ford, Gay N. (C)
Geier, Leo F. (C)
McRae, Don Lee (C)

PITTSBURGH

Carr, Robert E. (B)

PORTLAND

Doyle, Robley E. (B)
Robley, Asa A. (B)

PROVIDENCE

Tonseth, Didrick L. (C)

PUGET SOUND

Hildreth, George Thomas (B)
Kirksey, William W., Jr. (C)
Talbot, Thomas W. (C)

RICHMOND

Hogge, Otto L. (C)
Van Den Bogaerde, Gerard F. (C)

ROCHESTER

Garratt, David L. (C)

ST. LOUIS

Bach, Donald L. (C)

SAN DIEGO

Dyson, Elston G. (B)
Foster, Charles W. (B)
Hastings, Virgle H. (B)
Lewis, V. L. (B)
McGoyne, Norman Gene (C)
Norris, Charles H. (C)
Obloy, Felix (C)
Russell, Leslie W. (B)
Smith, William R. (C)

SAN FRANCISCO

Hance, Wilbur J. (C)
Nelson, Ray R. (B)
Pricer, Keith M. (D)
Schmid, Carl T. (D)
Vancott, Leonard R. (D)

SANGAMON VALLEY

Keck, Thomas A., Jr. (C)

SANTA CLARA VALLEY

Cozzo, Leon (D)
Dunakin, Robert B. (B)
Karlak, Robert Francis (C)
Martines, Dave T. (D)
Mattos, Ronald Fredrick (D)
McCandless, James (D)
Middaugh, Clark R. (C)
Mullins, William Y. (B)
Paxton, David F. (D)
Thorsen, Gary M. (D)
White, Allen (D)
Wilkins, William J. (D)

SUSQUEHANNA VALLEY

Bohan, Joseph (C)
Semion, Joseph (C)

SYRACUSE

Budynas, William D. (B)

WASHINGTON, D. C.

Conn, Darrell D. (B)
Harris, Henry R. (B)
Vicars, Earl Curtis (C)

WESTERN MASS.

Racliffe, William N. (B)

WICHITA

Brown, Harry C. (C)
Hoheisel, Vincent J. (C)
Stanberry, W. R. (B)

YORK-CENTRAL PA.

Macshane, Gordon H. (C)

MEMBERS NOT IN SECTIONS

Jain, Shantilal J. (C)
Mitchell, Alexander William (B)
Sonck, P. (C)

Members Reclassified During June

CHICAGO

Eyestone, John D. (C to B)

CLEVELAND

Irrgang, William (B to A)
Lincoln, J. F. (A to E)
Novy, Charles T. (D to C)

COLUMBUS

Martin, George E. (C to B)

NEW YORK

Kelly, Arthur M. (C to B)

NIAGARA FRONTIER

Padden, Charles F. (D to B)

PHILADELPHIA

Bilhardt, Lawson J. (C to B)

PUGET SOUND

Clark, Gerden H. (C to B)

SAN FRANCISCO

Marcellin, Wayne J. (D to C)

SANTA CLARA VALLEY

Skow, Ronald N. (C to B)

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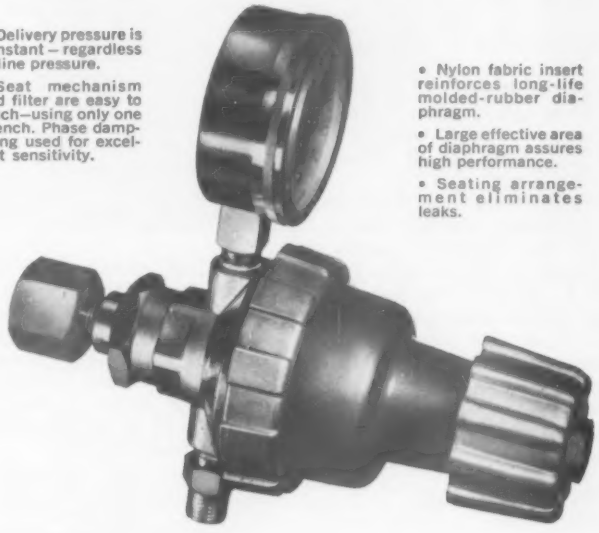

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NEWS of the industry

NCG Division Promotes Four

Four district promotions in the National Cylinder Gas Division of Chemetron Corp., producer of industrial and medicial gases, welding and cutting equipment and inhalation therapy equipment, have been announced by Clifford D. McGuinn AWS division vice-president.

Lawrence J. Roper was appointed district manager at Kansas City. He was previously manager in Puerto Rico and branch manager in Orlando, Fla.

Robert E. Buzard was appointed district manager at Portsmouth, Va. He was formerly assistant district manager at Columbus, Ohio.

Oscar F. Boerner was appointed assistant district manager at North Bergen, N. J. He was a medical department salesman for the company in Boston.

Lauren W. Sage was appointed assistant district manager at Cincinnati, Ohio.

Cleveland Company Joins Air Products, Inc.

It was announced recently that Compressed Gases of Ohio, Inc., Cleveland, has become a unit of Air Products, Inc. The Cleveland firm now supplies high-purity oxygen, acetylene, nitrogen, argon and other industrial gases in cylinder and bulk containers to concerns in that area. In addition, a complete line of electric and gas welding and cutting equipment and supplies will continue to be distributed. They will operate under the same name.

Stanley E. Fey, general manager, Industrial & Medical Gas Division of Air Products, Inc., pointed out that Compressed Gases of Ohio, Inc., will continue to serve the Cleveland area under R. William Metzger AWS as district manager and former president of Compressed Gases of Ohio, Inc.

William Metzger

Hold Welding Show

As part of a recent expansion program, Welder's Needs Inc. of Toledo, Ohio, held a public "Welderama" program. Two-day welding show was held in honor of the completion of the company's new warehouse facilities for the distribution of liquid oxygen for welding and medical uses.

Exhibits by the local AWS Section and a number of welding manufacturers, as well as live demonstrations of welding apparatus and techniques, were viewed by over 700 persons. Refreshments, door prizes and color sound movies rounded out the program.

Raymond Hoefler, Chairman of the AWS Toledo Section, was on hand to represent the Society and to explain the exhibit.

W. H. Morris, formerly a district representative for Linde Co., is president of the company and W. E. (Bill) Morris AWS is secretary-treasurer. H. W. Weide AWS is sales manager and coordinated the "Welderama."

Resistance-Welding-Machine Orders Increase

As of April 30th, new orders for resistance-welding machines and equipment received by members of the Resistance Welder Manufacturers' Assn., were 31% ahead of orders for the first four months of 1958, according to the monthly statistical report compiled by the Association's headquarters.

New business has been coming in at a rate of approximately $\$2^1/_2$ million per month thus far in 1959.

Shipments for the first four months were 15% above the same period of 1958. The past three months have all been close to $2 million in shipments.

For the third consecutive month, members reported backlogs of better than $\$7^1/_2$ million.

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

1959 National Fall Meeting:
September 28–October 1. Sheraton Cadillac Hotel, Detroit, Mich.

41st Annual Meeting and Eighth Welding Show:
April 25–29, 1960. Biltmore Hotel, Los Angeles, Calif.

ASM

Nov. 2–6, 1959. 41st National Metal Exposition and Congress. International Amphitheatre, Chicago.

WINS DISTRIBUTOR AWARD

Don Wyatt AWS of Mobile Welding Supply Co., Mobile, Ala., (right) receives "distributor-of-the-year" plaque from G. E. Sellstrom, president of Sellstrom Manufacturing Co., Palatine, Ill. Looking on is Mrs. Wyatt

KAISER WELDS CAST-ALUMINUM BUS BARS IN QUANTITY

Inert-gas-shielded metal-arc welding is the process used at the Ravenswood, W. Va. plant of Kaiser Aluminum & Chemical Corp. to join aluminum collector straps to "K-Slab" cast aluminum bus bars. More than 3 million lb of these bus bars have already been installed

MOBILE WELDING SUPPLIES

Valley Welding Supply Co. of Aurora, Ill., has taken to the "open road" with a mobile showroom of welding and cutting supplies and industrial gases. This concept has reportedly enlarged and intensified the firm's market area

Use Pureco CO_2 for LOW COST gas shielded metal arc welding

Pureco carbon dioxide, used as a gas shield by fabricators of mild steel, will provide quality welds with unusual economy.

Carbon dioxide is ideal for both single and multi-pass applications, manual or automatic, with large or small diameter wires. And now—you can also use CO_2 for *position* manual welding.

Your Pure Carbonic representative can give you the technical assistance you need and recommend a CO_2 supply system best suited for your particular operation. There are more than 100 Pureco locations from coast to coast for your convenience. Call or write today.

PURECO CO_2

Pure Carbonic Company

A Division of Air Reduction Company, Incorporated

150 EAST 42ND STREET, NEW YORK 17, N. Y.

AT THE FRONTIERS OF PROGRESS YOU'LL FIND AN AIR REDUCTION PRODUCT

For details, circle No. 10 on Reader Information Card

EXCELLENT OPPORTUNITY FOR ASSISTANT EDITOR

• **The *Welding Journal* is presently looking for a young engineer who may be interested in becoming an assistant editor on its staff.**

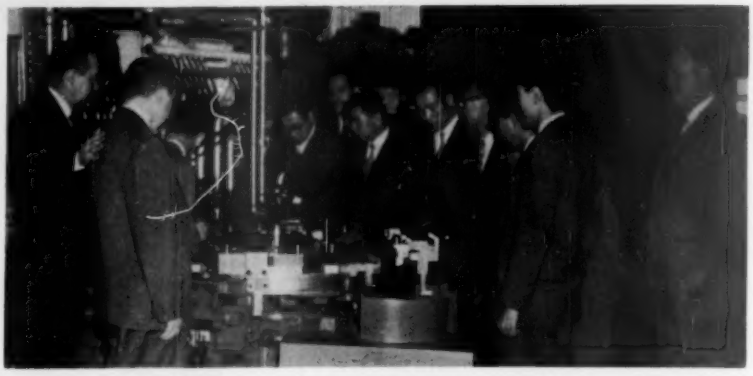
• The position we have open is a stimulating and challenging one; it affords an excellent opportunity to become proficient in all phases involved in the publication of a magazine. It calls for a technical man with a good background in the metal fabrication or metallurgical fields, who really likes to write and who can express himself clearly. Of course, this man should also have a pleasing personality and the ability to get along with others.

• Anyone interested in what we have to offer should send a resumé, including details of education, past experience and salary requirements, to

Editor
Welding Journal
American Welding Society
33 West 39th Street
New York 18, N. Y.

All replies will be held confidential.

JAPANESE WELDING EXPERTS VISIT U. S.



A team of 12 Japanese welding experts examine an automatic welding machine during a visit to the Progressive Welder Sales Co.'s Warren Alloy plant at Pontiac, Mich. These men were on a six-week tour of the United States to study automatic welding equipment for use in the automotive industry

New Hickinbotham Store Planned

Hickinbotham Bros., Ltd., broke ground recently for a new $35,000 welding supply store in Stockton, Calif., marking the start of a major expansion program for the firm. C. W. Cary, welding department manager for Hickinbotham, said the store should be completed by August 15th.

The new store will boast a modern installation for storing oxygen and filling conventional cylinders which was developed and manufactured by Linde Co., Division of Union Carbide Corp.

The company employs 60 persons, and its welding supply division operates a fleet of five trucks.

New Airco Liquid-Oxygen Plant

Air Reduction Pacific Co., a division of Air Reduction Co., Inc., has begun construction of a new $3,000,000 liquid oxygen, nitrogen and argon plant in Richmond, Calif. The new plant, which will produce daily 30 tons of the liquid products, will serve the missile, metalworking and steel industries in the San Francisco Bay area. Completion of the plant is expected by the end of 1959.

Nelson Field Organization Expands

Extensive expansion of its field organization responsible for the sale of Nelson stud-welding products has been announced by R. E. McGinnis, vice-president—sales, Gregory Industries, Inc., Lorain, Ohio.

Right now field engineers have been assigned as follows: Edward Sundberg, Los Angeles; Robert G. Pickering, Philadelphia; Charles W. Roberts, Birmingham; Robert Igoe, Buffalo-Rochester; John L. Harmon, Detroit-Toledo; Delmar V. Sprowls, Kansas City; Murray Gibbs and Paul Blake have been assigned to the company's Toronto, Canada, office.

Richard J. McGinn has been transferred from Houston to Cleveland as branch manager. S. A. Porter has been named acting manager in Texas, with temporary headquarters in Dallas.

A. E. Bosley has been appointed district manager in Los Angeles. He was replaced as field engineer in San Leandro, Calif., by Michael Davidson, formerly in the Los Angeles office.

Andrew J. Ramage, field engineer, was transferred from Birmingham to New Orleans, where he will be in charge of a new office.

Program of Two Day Conference on

Welding, Fabrication, Heat Treatment and Alloying of Titanium

to be held at New York University
Sept. 14-15, 1959

Monday, September 14th

WELDING AND HEAT TREATMENT	**Speaker**
1. Welding of Titanium and Titanium Alloys	Carl Hartbower Watertown Arsenal
2. Phase Equilibria and Kinetics for B 120 VCA	V. C. Petersen Crucible Steel Co. of America
3. B 120 VCA Heat Treatment Response	Nevzat Erkun Crucible Steel Co. of America
4. Studies in the Heat Treatment and Weldability of Ti – 13V – 11Cr – 3Al Beta Alloys	D. J. McPherson Armour Research Foundation
5. The Behavior of Spot and Fusion Welded RS 120 B (Ti – 13V – 11Cr – 3Al) and RS 140 (Ti – 5Al – 4Fe × Cr)	Henry Mattes Republic Steel Co.
6. Titanium Alloys for Solid Fuel Rocket Cases	P. Graef Curtiss-Wright Corp.
FABRICATION AND PROPERTIES	
7. Radiant Quartz Lamp Brazing of Titanium Honeycomb Structure	H. Schwartzbart Armour Research Foundation
8. The Effects of Fabrication Procedure on Properties of Ti – 6Al – 6V – 2Sn – 0.5Fe – 0.25Cu	Robert Colton Watertown Arsenal
Evening Program, Monday, September 14th	
9. The Extrusion of Ti – 7Al – 4Mo	Gunther Pfanner Republic Aviation Corp.
10. Performance and Applications of B 120 VCA	W. W. Wentz Crucible Steel Co. of America
11. Progress in Cold Fabrication of Titanium	Paul Frost Battelle Memorial Institute
12. Interrelationship of the Physical and Mechanical Metallurgy in the Fabrication of High-Strength Titanium Sheet Alloys	E. F. Erbin Titanium Metals Corp. of America
ALLOYING, HEAT TREATMENT AND PROPERTIES	
13. Ti – Al Phase Equilibria	Elmars Ence and Harold Margolin New York University
14. The Effects of Interstitials, Particularly Hydrogen, on Thermal Stability of High Al-containing Titanium Alloys	S. Seagle and S. Abkowitz Mallory-Sharon Metals Corp.
15. Problems in the Development of Titanium Alloys for Applications Above 800° F	G. A. Lenning Titanium Metals Corp. of America
16. The Development of Titanium 800° F Base Alloys for Use at 1200–1800° F	J. P. McAndrew Armour Research Foundation
17. The Periodic Table—Key to High-Temperature Titanium Alloy Development	D. Dickinson and R. Nylen Mallory-Sharon Metals Corp.
CORROSION	
18. The Electrochemical and Corrosion Behavior of Titanium and Titanium Noble Metal Alloys	Milton Stern Union Carbide Metals Research

For further information, contact Dr. H. Margolin, New York University, University Heights, New York 53, N.Y.

Tempilstik°

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**Also Tempil° Pellets and Tempilaq° (liquid form)*

Tempilstik°—a simple and accurate means of determining preheating and stress relieving temperatures in welding operations. Widely used in all heat treating—as well as in hundreds of other heat-dependent processes in industry. Available in 80 different temperature ratings from 113°F to 2500°F . . . $2.00 each.

Send for *free* sample Tempil° Pellets. State temperature desired . . . Sorry, no sample Tempilstiks°.

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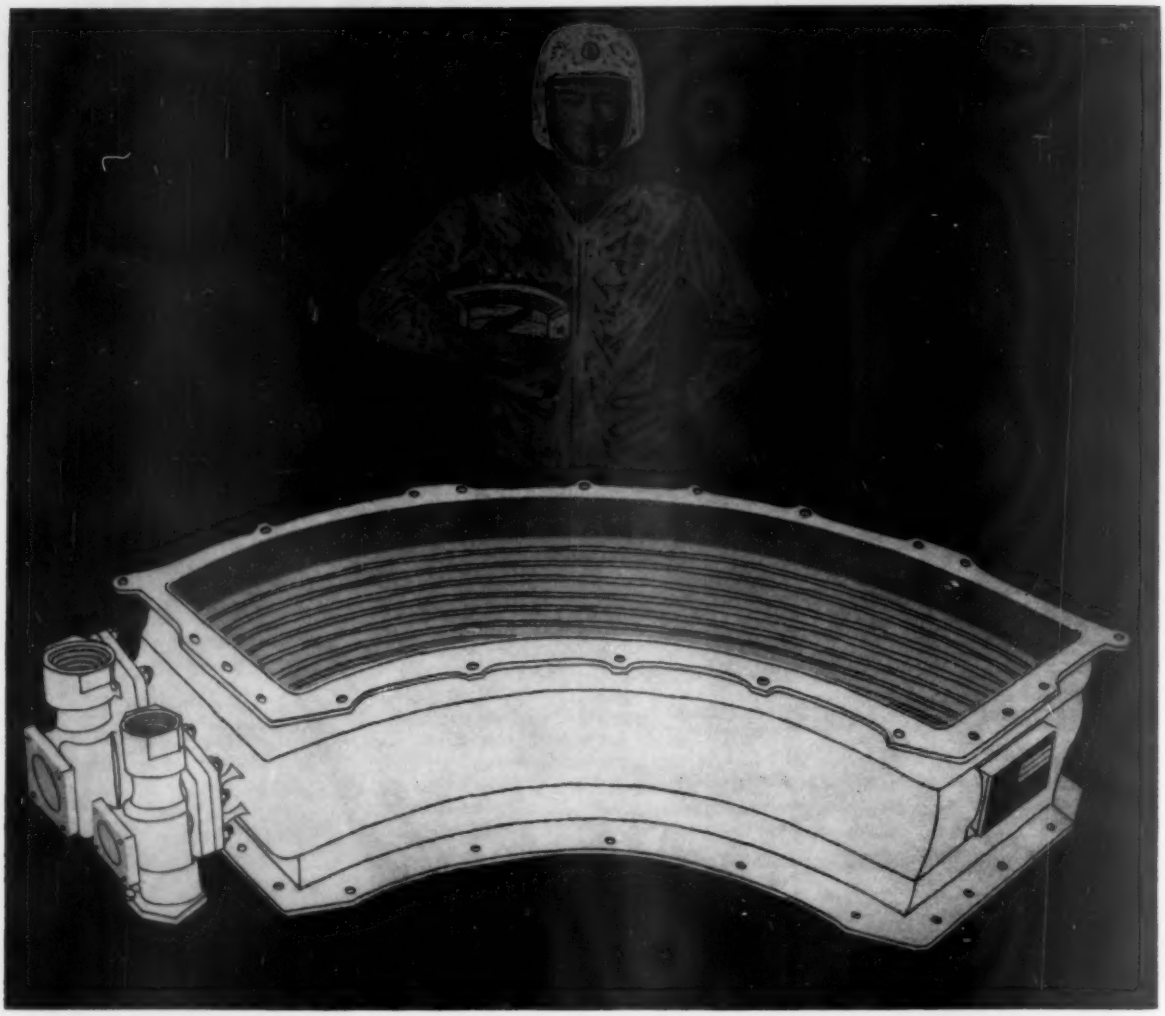
132 West 22nd St New York 11 N Y

For details, circle No. 12 on Reader Information Card

South Wind Division of Stewart-Warner Corporation builds this heat exchanger of Alcoa Aluminum. It is used in such high-performance aircraft as the Boeing B-52 jet bomber. Fins are die formed, separator plates blanked. Unit is then dip brazed to insure uniform quality, strong joints.



DIP-BRAZED ALCOA ALUMINUM HEAT EXCHANGERS GIVE JET-AGE PERFORMANCE, CUT JET-AGE COSTS

An engine oil cooler in a jet engine, often operating at supersonic speeds and stratospheric altitudes, has to be dependable. Joints or fins can't fail. To insure dependability, South Wind Division of Stewart-Warner Corporation builds oil coolers of dip-brazed Alcoa® Aluminum. The result is a strong, lightweight and easily fabricated unit that is produced economically and efficiently.

South Wind has also found that there are other good reasons for using the aluminum dip-brazing process. "We chose dip brazing because it yields the most consistent quality joint," says J. Q. Mosbarger, manager of South Wind's Sales and Engineering Administration. "We also prefer aluminum because it permits a heat exchanger design with 33 per cent less weight, it increases exchanger efficiency three to four times over its closest alternate metal. It is the most economical metal, pound for pound, we could use."

For heat exchangers or for similar applications, dip-brazed Alcoa Aluminum is the ideal solution because it produces complicated assemblies in one-piece, uniformly strong units. Closer tolerances in small parts are possible, and over-all strength can be easily controlled.

For details, circle No. 13 on Reader Information Card

Any of the distributors listed at the right can give you full information on aluminum welding and brazing processes. Or, write Alcoa direct for free information and loan of films on joining aluminum. Write to Aluminum Company of America, 1762-H Alcoa Building, Pittsburgh 19, Pa.

ALCOA ALUMINUM

Your Guide to the Best in Aluminum Value

For Exciting Drama Watch "Alcoa Theatre," Alternate Mondays, NBC-TV, and "Alcoa Presents," Every Tuesday, ABC-TV

Want technical help in welding, brazing or soldering aluminum? Contact your Alcoa sales office, listed under "Aluminum" in the Yellow Pages of your phone book.

For immediate delivery of Alcoa welding products, call your Alcoa outlet listed below. He carries a complete range of alloys and sizes.

ALABAMA
Birmingham
Hinkle Supply Co.

CALIFORNIA
Los Angeles
Ducommun Metals & Supply Co.
Pacific Metals Company, Ltd.
San Francisco
Pacific Metals Company, Ltd.

COLORADO
Denver
Metal Goods Corp.

CONNECTICUT
Milford
Edgcomb Steel of New England, Inc.
Windsor
Whitehead Metals, Inc.

FLORIDA
Jacksonville
The J. M. Tull Metal & Supply Co., Inc.
Miami
The J. M. Tull Metal & Supply Co., Inc.
Tampa
The J. M. Tull Metal & Supply Co., Inc.

GEORGIA
Atlanta
The J. M. Tull Metal & Supply Co., Inc.
Mid-South Oxygen Company

ILLINOIS
Chicago
Machinery & Welder Corp.
Steel Sales Corp.

KANSAS
Wichita
Metal Goods Corp.

KENTUCKY
Louisville
Williams and Co., Inc.

LOUISIANA
New Orleans
Metal Goods Corp.

MARYLAND
Baltimore
Southern Oxygen Co.
Whitehead Metals, Inc.
Bladensburg
Southern Oxygen Co.

MASSACHUSETTS
Cambridge
Whitehead Metals, Inc.

MICHIGAN
Detroit
Steel Sales Corp.

MISSOURI
Kansas City
Metal Goods Corp.
St. Louis
Metal Goods Corp.
Steel Sales Corp.

NEW HAMPSHIRE
Nashua
Edgcomb Steel of New England, Inc.

NEW JERSEY
Harrison
Whitehead Metals, Inc.

NEW YORK
Buffalo
Whitehead Metals, Inc.
New York
Whitehead Metals, Inc.
Syracuse
Brace-Mueller-Huntley, Inc.
Whitehead Metals, Inc.

NORTH CAROLINA
Greensboro
Southern Oxygen Co.

OHIO
Cincinnati
Williams and Co., Inc.
Cleveland
A. M. Castle & Co.
Williams and Co., Inc.
Columbus
Williams and Co., Inc.
Toledo
Williams and Co., Inc.

OKLAHOMA
Tulsa
Metal Goods Corp.

OREGON
Portland
Pacific Metal Co.
J. E. Haseltine & Co.

PENNSYLVANIA
Philadelphia
Edgcomb Steel Co.
Southern Oxygen Co.
Whitehead Metals, Inc.
Pittsburgh
Williams and Co., Inc.
York
Southern Oxygen Co.

TENNESSEE
Kingsport
Southern Oxygen Co.

TEXAS
Beaumont
Big Three Welding Equip. Co.
Corpus Christi
Big Three Welding Equip. Co.
Dallas
Metal Goods Corp.
Texas Welding Supply Co.
Houston
Metal Goods Corp.
Big Three Welding Equip. Co.
San Antonio
Big Three Welding Equip. Co.

UTAH
Salt Lake City
Pacific Metals Company, Ltd.

VIRGINIA
Norfolk
Southern Oxygen Co.
Richmond
Southern Oxygen Co.

WASHINGTON
Seattle
Pacific Metal Co.
J. E. Haseltine & Co.
Spokane
J. E. Haseltine & Co.

WISCONSIN
Milwaukee
Machinery & Welder Corp.
Steel Sales Corp.

All-State Appoints New Distributors

New distributors for All-State Welding Alloys Co., White Plains, N. Y., are Elyria Supplies Co., 118 Kipling St., Elyria, Ohio, and the Ballach Co., 420 S. W. 7th St., Des Moines, Iowa. The announcements were made by T. D. Nast, All-State president.

NCG Opens New Oakland Office

Establishment of a West Coast regional accounting office at 1143 First Western Building, Oakland, Calif., is announced by the National Cylinder Gas Division of Chemetron Corp. H. C. Booth is regional accountant in charge.

Other NCG facilities in the area include a district sales office and an oxygen and acetylene producing plant at 1588 Doolittle Dr., San Leandro.

Promoted by Superweld

William J. Bradley has been appointed factory manager and a member of the management committee and Kenneth L. Madden AWS has been named manager of quality control at Superweld Corp., North Hollywood, Calif., high-temperature brazing concern.

Mr. Bradley was formerly general manager and chief engineer in charge of product design for Earth Equipment Corp. of Los Angeles. He was also connected with Lockheed Aircraft Corp. as a member of Georgia Division planning staff, and with Detroit Farm Equipment Corp. and Tractor Sales Corp. He is a graduate of California State Polytechnic College and served overseas with Army Ordnance in the South Pacific during World War II.

Mr. Madden, who will directly supervise all inspection and quality control personnel, comes to Superweld from Electronic Welding Co., where he was plant manager. Prior to that post, he was a welding engineer at Boeing Aircraft in Seattle and plant superintendent at Sweden Freezer Manufacturing Co. He is a member of the AWS and the Society of Professional Engineers.

Kenneth R. Madden

Harnischfeger Names Distributor

Harnischfeger Corp., Milwaukee, Wis., has appointed Arizona Products & Machine Co., Phoenix, Ariz., as distributor for its complete line of welders, electrodes and welding positioners. Ted Collins is president, and Allan Jeffryes, vice-president.

New Officers Elected by ASTM

The American Society for Testing Materials, a 16,000-member professional organization concerned with research and standards for materials, recently announced the election of new officers.

F. L. LaQue of the International Nickel Co. is the new president. Miles N. Clair of Thompson and Lichtner Co. is vice-president and A. Allen Bates, Portland Cement Assn., is senior vice-president.

The announcements were made at the 62nd Annual Meeting held in June at Atlantic City, N. J.

Arcos New England Office Moved

The New England District Office of Arcos Corp., Philadelphia manufacturer of welding electrodes and rods, has been moved to 45 Kearney Rd., Needham Heights, Mass. The postal address is now P. O. Box 204, Needham Heights, and telephone number: Hillcrest 4-4088-9. The office was formerly located at 28 Travis St., Boston.

Changes at Whitehead

A series of promotions at Whitehead Metals, Inc. has elevated E. W. Lothman to senior vice president and C. J. Bianowicz to general sales manager for all products of Inco's Huntington Alloy Products Division. Mr. Bianowicz was also elected a director and assistant vice president of Whitehead. In addition, E. L. Carey has been elected secretary of the company and F. A. Fink has been appointed assistant to the vice president and assistant treasurer.

In other moves, three new Whitehead branch managers have been named: C. S. Newmarch at Philadelphia, J. I. Doherty at Cambridge, Mass. and C. C. McCarthy at Windsor, Conn.

PERSONNEL

Air Reduction Appoints Twining

E. S. Twining, Jr., manager, gas department—marketing, has been appointed vice-president—marketing, according to an announcement by R. E. Lenhard, president of Air Reduction Sales Co., the industrial gas and welding products division of Air Reduction Co., Inc. G. L. Werly, Jr., succeeds Mr. Twining as manager, gas department—marketing.

Mr. Twining has held various sales management positions during his 14 years with Air Reduction. He was assistant sales manager of the Philadelphia district sales office from 1947 to 1952; and from 1952 to 1956 held the position of manager of Airco's Boston district sales office. In 1956, Mr. Twining was appointed assistant manager of the gas sales department in New York, and a year later was named manager, gas department—marketing, the position he has held up to this time.

Michaels Given Honorary Degree

Ernest E. Michaels AWS, president of Chicago Bridge & Iron Co., was awarded an honorary Doctor of Engineering degree by South Dakota State College, Brookings, during commencement exercises on June 8th.

Mr. Michaels was graduated from South Dakota State in 1920 with a B.S. degree in Civil Engineering. He received his master's degree from the University of Illinois in 1922.

Long a prominent figure in the steel-plate fabricating industry, Mr. Michaels has been president of Chicago Bridge & Iron Co. since 1956 and a director of the company since 1946.

He is also executive committee chairman and immediate past president of the Steel Plate Fabricators Assn., and chairman of the Welding Research Council of the Engineering Foundation.

Wooding Receives Award

The Drexel Alumni Award for outstanding performance in the field of engineering was recently presented to Walter H. Wooding AWS.

Mr. Wooding, who recently joined the research and engineering department of Arcos Corp., was previously civilian head of the Philadelphia Navy Yard's Industrial Test Laboratory.

He received the AWS 1953 Lincoln Gold Medal, the Navy's Meritorious Civilian award in 1954 and is a registered professional engineer in Pennsylvania.

Cass, Demos Promoted by Foote Mineral

Boyd E. Cass AWS has been named General Sales Manager of Foote Mineral Co., it has been announced recently by James Fentress, director of marketing. Mr. Cass has been with the company since 1945 and previously served as manager of metallurgical sales. He is a graduate of Grove City College and a resident of Glenside, Pa.

Anthony C. Demos, formerly sales engineer with Foote, has been promoted to manager of metallurgical sales. Mr. Demos joined Foote in 1948 as a research engineer and has been in metallurgical sales for the past five years. He is a graduate of the University of Virginia and received his M.S. degree from University of Pennsylvania in 1952. He is a resident of King of Prussia, Pa.

OBITUARY

George Schneider

George Schneider AWS died on May 6, 1959. He was vice-president of Rayno Distributors Inc. A member of the Long Island Section, he joined AWS in 1937.

Peterson and Neil Appointed

Harnischfeger Corp. Welder Division has added two representatives to its sales staff: Paul H. Peterson, who will cover the southern half of Chicago and parts of Illinois and Indiana, and Alfred Q. Neil who will cover the northern half of Chicago and upper portions of Illinois and Iowa.

Dall Promoted by Linde

J. J. Dall has been appointed assistant general manager, Electric Welding, Linde Co., Division of Union Carbide Corp., New York. His responsibilities will include all phases of arc welding processes. Mr. Dall was formerly general manager of a smaller Linde department where these electric welding processes were used extensively.

Mr. Dall joined the Linde Co. in 1946 in the New York District and his wide background with Linde includes positions in Wichita, Kans., San Antonio, Tex.; Houston, Tex.; and Youngstown, Ohio. He is a graduate of Cornell University.

E. S. Twining, Jr.

Boyd E. Cass

W. H. Wooding

Welding Engineer

qualified to conduct welding development, research and testing on high temperature alloys. Required by independent progressive research company. Phone or write **Metcut Research Associates Inc., 3980 Rosslyn Drive, Cincinnati 9, Ohio, BRamble 1-5100.**

EMPLOYMENT SERVICE BULLETIN

Services Available

A-722. Young successful sales engineer seeks permanent connection in industrial sales N. Y. Met. area. No relocation. 12 years' successful experience selling to utilities, contractors and industrials. Will consider investing in growing business as partner.

Positions Vacant

V-375. Welding Engineer. Engineering graduate with minimum of five years experience in fabrication and metallurgy involving covered electrodes and automatic arc welding processes, steel, aluminum. For Welding Engineering Department of manufacturer of welding electrodes and wire in Baltimore area.

V-376. Research Engineer. Recent BS graduate for Research and Development Department of manufacturer of welding electrodes and wire in Baltimore area. Background in laboratory and development work desirable. Possibility for rapid advancement in a large company.

WELDING ENGINEERS

Welding Section of Manufacturing Research and Process Department has excellent opportunities for college graduates with BS in engineering or science plus 3 years' experience in welding. The applicants selected will conduct research and development programs in welding and act as welding consultants to engineering and production departments regarding the application of welding processes. Experience in aircraft manufacturing preferred, though not essential.

Salary commensurate with experience and ability to work with a high degree of independence.

Send resume in confidence to:
MR. WILLIAM WALSH
Employment Office

REPUBLIC AVIATION
Farmingdale, Long Island, New York

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MAN OF ACTION!

As SALES MANAGER for

LEADING LINE OF WELDING POSITIONERS—TURNING ROLLS AND FIXTURES FOR AUTOMATION WELDING. Must be thoroughly familiar with Welding Industry, both processes and distribution. Prefer man between 35–45 with background in Sales Management. Excellent opportunity if you meet these qualifications. Please send full resume with first letter; include past earning record. Of course all replies will be treated in strictest confidence.

Box V-372.
WELDING JOURNAL

WELDING ENGINEERS

Graduate Engineers with degrees in Welding, Mechanical, Metallurgical or Electrical Engineering, with 3 to 5 or more years experience in Welding Research and Development, Weldment Design, and Production Welding Operations. Aggressive, open-minded individuals sought. Send resume to:

Employment Section
ACF Industries, Inc.
P. O. Box 1666
Albuquerque,
New Mexico

SALES ENGINEER

Established company seeking man with electrical engineering degree plus experience in the field of welding equipment. He will be responsible for consultation on machine work, will be required to service customers and distributors, and will be expected to be able to evaluate new products. About 50% of time will be spent in traveling. Car furnished, expenses paid, liberal benefits with good starting salary. Please include in confidential reply all details relating to education and experience.

Box No. V-371
WELDING JOURNAL

24′dia. expansion joints

Stainless steel expansion joints
for penstocks 24 feet in diameter
are no easy job for the fabricator.

It is a problem of fixturing,
metallurgy and welding.

Alert Steel Products Company
took the job and
were successful on the first try.

Before beginning to tool up,
Mr. Jules Davis, Alert's President,
called in the man
who specializes in welding problems—
the Lincoln Welding Engineer.

The Lincoln man, Tom Farris,
suggested submerged arc welding
with a "Mechanized Squirt"
18/8 wire and a special flux
for welding stainless—ST-100.

Then, Mr. Farris and Mr. Ed Klein,
Alert's Chief Engineer,
planned the fixturing to give
rigid support while welding.

fabricated in stainless

by Submerged Arc Welding

Result: On the first try
the 10,000-pound ring
(one-half of one joint)
was welded in eight separate pieces,
to give a total tolerance
of 1/16-inch upon assembly.

Tests found the weld structure perfect
and analysis as predicted.

If you have tough welding problems,
call your Lincoln Welding Engineer, today!

THE LINCOLN ELECTRIC COMPANY • Dept. 1958 • Cleveland 17, Ohio
The World's Largest Manufacturer of Arc Welding Equipment

LINCOLN

For details, circle No. 14 on Reader Information Card

New Literature

1958 Supplement to AWS Bibliographies Available

The AMERICAN WELDING SOCIETY has announced the availability of the 1958 Supplement to the AWS Bibliographies. The original publication contained bibliographies of articles which appeared in the WELDING JOURNAL from 1937 through 1957.

The Bibliographies previously issued listed articles under 28 subject headings. The Supplement contains listings of all articles appearing in the WELDING JOURNAL from January through December 1958. The complete Bibliographies thus provide a record of all articles on welding, welding research and related subjects which have appeared from 1937 through 1958.

The Supplement has been designed for use as issued or as supplementary material to bring previously issued AWS Bibliographies up to date. The format is identical and entries under a given subject are contained on one or more pages. Each page is punched to facilitate insertion into the original Bibliographies under the respective subject headings.

The compilation of these data is performed as a service to industry to eliminate the time-consuming examination of technical literature in the search for information on a given subject.

Copies of the 1958 Supplement to the AWS Bibliographies may be obtained at a cost of $1.50 from the AMERICAN WELDING SOCIETY, Department T, 33 W. 39th St., New York 18, N. Y.

NEMA Welding Text

Arc Welded Joints, a supplementary text for use in elementary college courses on Strength of Materials, has been published by the Arc Welding Section of the National Electrical Manufacturers Assn.

The booklet is divided into two parts. The first part defines the types of welds and joints most commonly used, and gives examples of methods used for analyzing the strength such joints have in design. Part II describes the general methods of operation for manual and automatic welding and shows examples by means of half-tone illustrations and schematic drawings.

The material is designed to fill the gap which exists in most engineering courses. Textbooks in general use introduce the student to the principles of riveted and bolted design, but rarely devote comparable space to welded design and construction. It is hoped that those concerned with the teaching of such engineering courses will use the booklet in conjunction with their engineering text. By this means the student will obtain a grounding in elementary arc welding principles and processes.

Single copies are available free of charge to educators concerned with the teaching of engineering courses. A charge of 25¢ is made to students desiring the booklet. Copies of *Arc Welded Joints* are available from the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

Carbon-dioxide Welding

Air Reduction Sales Co., 150 E. 42nd St, New York 17, N. Y., has issued a new 24-page booklet on gas-shielded metal-arc welding of mild steel and low-alloy steels with carbon dioxide (CO_2) shielding gas. The manual provides an illustrated description of both the conventional CO_2 and the recently announced dip transfer CO_2 processes.

Divided into three sections, the booklet covers the fundamentals of the process with descriptions of outstanding characteristics; how both conventional and dip transfer welding are applied to specific jobs; and the equipment used in metal-arc CO_2 welding. The latter section covers manual welding guns and automatic welding heads, wire feeders, controls, welding wires, power supplies and carbon-dioxide equipment.

For your free copy, circle No. 63 on Reader Information card.

1958 Book of ASTM Standards

The American Society for Testing Materials has completed publication of its 10-part *1958 Book of ASTM Standards*. ASTM standards are used to cover production, purchase and evaluation of millions of dollars worth of material annually.

The increase from 7 to 10 parts in 1958 was necessitated by a growth in size of individual parts to the point where they could no longer be bound economically and were becoming unwieldly in size.

The statistics alone on this reference work are impressive. Within the 10 parts are contained 24,500 standard specifications, methods of test, definitions of terms and recommended practices. These will occupy 13,600 pages.

Each part is complete with a detailed subject index and a list of standards in numeric sequence.

To keep this book up to date, supplements will be issued to each part late in 1959 and 1960. As a service, a complete index is furnished without charge with each set of the *Book of ASTM Standards*.

For details, circle No. 64 on Reader Information Card.

Flux-cored Electrodes

A new product bulletin on Arcos-arc flux-cored electrodes and semiautomatic wire-feed equipment has been issued by Arcos Corp., 1500 S. 50th St., Philadelphia.

The four-page bulletin also serves as an instruction manual. It describes the simple, portable equipment with nonelectronic controls needed for CO_2 semiautomatic and automatic welding of mild and low-alloy steels. Then, by means of a picture of the unit and a diagrammatic sketch of the hook-up, it shows the process in use.

The unique, service-type bulletin not only presents features and specifications of the equipment, but goes on to explain the basic operating principles by which it works. It also gives instructions for connecting and using the unit and explains the function of the unit's electrical parts.

For your free copy, circle No. 66 on Reader Information Card.

Brazing-alloy Flow Control

A new $8^1/_2$ x 11, two-color engineering data sheet (Number 2.2.7) describing Nicrobraz Red Stop-Off for brazing-alloy flow control is now available from Stainless Processing Division, Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich.

The new sheet describes the product's uses and properties. Application recommendations and instructions for Stop-Off removal following brazing are also included.

For your free copy circle No. 68 on Reader Information Card.

Spot-welding Machines

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., introduces Bulletin 318–1 completely describing the Sciaky Type SPT-2 Spot Welder and the EPT-2 Projection Welder.

This brochure fully describes the machines and is supplemented with dimensional drawings and illustrations. The tooling required to convert the EPT-2 from projection to spot welding is also shown. Machine data are tabulated to indicate kva range, throat depths, welding capacities, electrode forces, etc.

For your free copy, circle No. 69 on Reader Information Card.

Pipe Welding

Two technical articles on small pipe welding, written by A. N. Kugler, chief welding engineer, Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y. have been issued in booklet form by Airco. These two articles, entitled "Fabrication of Small Piping by Welding and Brazing" and "Designing for Welded Systems of Small Size Pipe," appeared originally in successive issues of the magazine *Air Conditioning, Heating and Ventilating.*

The articles were prepared to acquaint contractors, journeymen and apprentices in the plumbing and pipefitting industries with the requirements for this class of work. They will also be of interest to those engaged in the installation of small-size noncritical piping such as radiant heating and snow melting systems.

For your free copy, circle No. 71 on Reader Information Card.

Aluminum-bronze Alloy

Stress-corrosion cracking is described in a new bulletin, *The Ampco Technical Review,* published by Ampco Metal, Inc., 1745 S. 38th St., Milwaukee 46, Wis.

The illustrated, 4-page bulletin reveals the development of an aluminum bronze alloy which successfully combats intergranular stress-corrosion cracking without weakening the alloy's general corrosion and cavitation-erosion resistance, workability and high mechanical properties.

Welding characteristics, forming, drawing and machining procedures and physical properties of the new alloy are also included.

Typical corrosion applications in the chemical, petroleum and paper industries are given for the new alloy, while effective uses in the marine and power-generating industries are mentioned.

For your free copy, circle No. 72 on Reader Information Card.

Heat-treating Equipment

Atmosphere heat treating applications are covered in a Ferrotherm Co. Newsletter just released. Actual case histories showing the applications of heat treating in hydrogen and other protective atmospheres on such processes as cycle annealing, furnace brazing, stress relieving, solution heat treating, precipitation hardening, etc., on materials such as 347 and 304SS, Vascojet, A-286, 17–4 and 17–7PH, Beryllium and Inconel are given. Also describes applications of simultaneous brazing and hardening of aircraft stainless parts and heat treatments of nuclear components.

For your free copy, circle No. 73 on Reader Information Card.

Stainless-steel Fittings

New light-wall stainless-steel fittings and flanges for noncritical process piping are described in a six-page bulletin available from Tube Turns Division of Chemetron Corp., Louisville 1, Ky.

The new line features long tangent fittings, unique rotating insert flanges and a reversible plug-and-cap.

Illustrations show different methods of joining light-wall fittings and pipe, including a sequence of photos on making "rolled in" flanged assemblies. Charts give dimensions of the new line of fittings and flanges, design properties of 5S and 10S pipe and dimensional tolerances.

For your free copy, circle No. 75 on Reader Information Card.

Metal Cleaner

The cleaning of metals with Oakite "Room-Temp Cleaner" is described in Folder F10596, recently published by Oakite Products, Inc., 157 Rector St., New York 6, N. Y.

Designed primarily for use in spray washing machines, the compound is most frequently used in

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temperature range of 80 to 100° F. At such temperatures, washing solutions require considerably less expensive heating, and there is less loss of heat through absorption by the metal being processed. There is a similar saving in air-conditioning costs, as well, since conditioning equipment has less heat to counteract. Working conditions are said to improve.

The booklet also points out the material's ability to retard rusting of steel between operations; its safety on steel, aluminum, copper, brass, and zinc, and their alloys.

For your free copy, circle No. 51 on Reader Information Card.

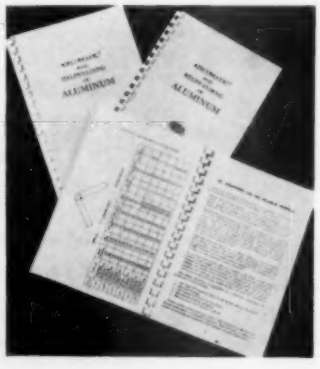
Welding Stainless Steel

Welding engineers and others associated with the fabrication and installation of process piping and tubing will be interested in the information contained in a folder released by the Tubular Products division of The Babcock & Wilcox Co., Beaver Falls, Pa. Known as TDC 162, the publication provides information on the welding characteristics of both austenitic and ferritic types of stainless steel. Also included is a table indicating electrodes, preheating and post-welding heat treatments to be used in joining the stainless steels to each other and to dissimilar metals.

For your free copy, circle No. 76 on Reader Information Card.

Aluminum Welding

A comprehensive survey of the techniques of welding aluminum using gas-shielded metal-arc and inert-gas tungsten-arc processes has been issued by Air Reduction Sales Co., a division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y. This 120-page spiral bound book, entitled "Aircomatic and Heliwelding of Aluminum," thoroughly covers the entire subject from a brief historical note on the first uses of these processes for welding aluminum to the highly specialized aluminum fabrications which are being welded with them today.



Major topics covered include weldability of aluminum and its alloys, definitions and technical discussions of the two welding processes, selection of the proper process for certain job applications, descriptions of manual and automatic equipment, welding power supplies and safety practices.

The book is illustrated with one hundred photographs, charts and detailed diagrams of Aircomatic and Heliwelding equipment and techniques.

For your free copy, circle No. 77 on Reader Information Card.

Nuts and Fasteners

A complete line of various clinch, pilot and weld nuts in standard and special types are fully described in a new 16-page, liberally illustrated general catalog now available from the McLaughlin Co., 212 Jaikins Bldg., Birmingham, Mich. Specifications and applications for all fasteners in the McLaughlin series are given.

Featured in the catalog is a patented new quick-attachment expansion nut suitable for use in either manual or automated fastening applications.

Also provided are ready-reference tables on recommended nut torque and pertinent screw-thread information.

For your free copy, circle No. 78 on Reader Information Card.

Nondestructive Testing

A new two-page bulletin describing the apparatus used in nondestructive testing of solid materials by induced sonic vibrations is now available from Soiltest, Inc., 4711 W. North Ave., Chicago 39, Ill.

The apparatus induces continuous sonic vibrations into samples of concrete, metal and other solids and permits comparison of initially induced vibrations and vibrations transmitted through the sample. The device can be used to measure transverse and torsional resonant frequencies and strengths and also to determine Young's Modulus of Elasticity.

For your free copy, circle No. 80 on Reader Information Card.

X-raying of Pipelines

A new booklet on the use of X-ray photography in the construction of pipe lines has just been announced

by the Gevaert Company of America, Inc. The booklet contains data on techniques of circular assembly joints, inspection of welded joints and a data table on the use of Structurix Industrial X-ray films.

The booklet also outlines the use of isotope carriers in inspections and the double-wall technique of inspections. It closes with a tabulation of welding defects which are due to improper preparation of the joint, and defects due to welding techniques.

For your free copy, circle No. 81 on Reader Information Card.

Brazing Alloys

A new single-page engineering data sheet, No. 170, discussing Phos-Sil 15, a copper-phosphorus-silver alloy for brazing nonferrous metals, is available from American Brazing Alloys Co., P. O. Box 11, Pelham, N. Y.

The data sheet includes physical and chemical properties and lists specifications to which Phos-Sil 15 conforms.

For your free copy, circle No. 83 on Reader Information Card.

Air Force Titanium Reports

Air Force reports describing two promising titanium alloys, one an active-eutectoid base material with excellent tensile properties at 1200° F and the other a heat-treatable sheet alloy with yield strength of 160,000 psi, have just been released to industry through the Office of Technical Services, U. S. Department of Commerce.

A report of Air Force research into the chemistry of titanium which concludes that divalent titanium does not exist to any appreciable extent in solution also is available. The three volumes are:

Development of Active-Eutectoid Base Alloys. R. F. Bunshah and H. Margolin, New York University for Wright Air Development Center, U. S. Air Force, October 1958, 51 pp. (Order PB 151518 from OTS, U. S. Department of Commerce, Washington 25, D. C., $1.50.) An alloy of Ti – 6Cu – 7Al – 6Zr with tensile strength of 108,900 psi at 1200° F was outstanding among several which showed promise for use in the 1000 to 1200° F range. The materials were developed during a study of the active eutectoid titanium alloy system, in which the decomposition of the beta phase to alpha plus compound occurs very rapidly. Titanium-copper base alloys were systematically alloyed with alpha strengthening additions of aluminum and/or tin and/or zirconium. The outstanding alloy also showed tensile strength of 165,000 psi in the annealed condition at room temperature. The drop-off in tensile strength with increasing temperature was found to come above 1000° F in this type of alloy, a factor which increases their useful high-temperature potential. Rupture life at 1000° F was very good. The best strengthening agents were found to be aluminum, copper, zirconium and tin, in that order.

Development of a Heat-Treatable Titanium Sheet Alloy. C. R. Lillie and D. W. Levinson, Armour Research Foundation for Wright Air Development Center, U. S. Air Force, August 1958, 92 pp. (Order PB 151279 from OTS, U. S. Department of Commerce, Washington 25, D. C., $2.25.) A modified alpha-beta composition, Ti – 3Al – 7Mo – 0.25Be, provided 160,000 psi yield strength for 0.2% offset at room temperature, the strength requirement for heat-treatable titanium sheet alloys developed during this program. The strengthening value of beryllium content was shown by the fact that straight alpha-beta alloys failed in strength and/or ductility when interstitials were low. The alloy also displayed reasonable uniform elongation, stability for 500 hr at 800° F under 25,000 psi stress, and good yield-ultimate ratio after proper solution treatment. A Ti – 2.5Al – 7(9)Mn alloy had similar promising properties except for yield-ultimate ratio, which was high, and uniform elongation, which was poor. A particular recommendation growing out of the study was for further investigation of strengthening by small additions of beryllium, since no other precipitation-hardener had proved successful in titanium alloys.

The Chemistry of the Lower Valences of Titanium. T. C. Franklin and H. V. Seklemian, Baylor University for Wright Air Development Center, U. S. Air Force. September 1958, 63 pp. (Order PB 151485 from OTS, U. S. Department of Commerce, Washington 25, D. C., $1.75.) A study was conducted to identify and characterize the lower valence states of titanium (normally tetravalent) to determine whether divalent compounds have stable existence. Several methods for the preparation of divalent tita-

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nium were investigated. None produced identifiable quantities of divalent compounds. It was concluded that divalent titanium does not exist to any great extent in solution, and that much of the literature on alleged divalent compounds probably describes a corresponding trivalent substance. Electrochemical experiments, using both dissolution and deposition techniques, confirmed the observation that the lowest stable valence of titanium in solution is three. Divalent titanium appeared so powerful a reducing agent that oxidation by ordinary solvents proceeds preferentially to any further electrochemical reduction, defeating attempts to plate the metal from media other than fused salts.

Nondestructive Testing

A 12-page booklet on the use of X and gamma rays for nondestructive inspection and product testing has been published by Picker X-Ray Corp., 25 S. Broadway, White Plains, N. Y.

The illustrated booklet, titled "Are You In This Profit Picture?," considers the advantages and disadvantages of both X-ray and gamma ray for inspection purposes.

Included in the booklet are examples of current industrial applications of X-ray and radioisotope machines used in foundries, factories, airframe construction and maintenance, and shipbuilding.

One section of the new publication deals with the effects of radiation on a product to improve its quality or to reduce production costs. Charts show the physical, chemical and biological effects of various dosages of radiation.

For your free copy, circle No. 53 on Reader Information Card.

Guide for Carbon Steels

Peter A. Frasse & Co., Inc., 17 Grand St., New York 13, N. Y., has announced the availability of a new $8^1/_2$ x 11-in. chart, Sec. E, No. 1, with which carbon-steel government specifications can be identified.

The chart shows the chemical analysis requirements for 60 most frequently used military and federal specifications. Also listed are specified forms such as sheets and bars and nearest corresponding SAE, AISI and AMS type numbers.

For your free copy, circle No. 54 on Reader Information Card.

X-ray Units

A new catalog describing the Baltograph 180 Panoram-X industrial X-ray unit has been announced by Balteau Electric Corp., New and Meadow Sts., Stamford, Conn. Complete specifications of the equipment are included along with photographs depicting typical uses and data on suggested applications.

For your free copy, circle No. 56 Reader Information Card.

Beryllium-copper Alloys

Information on beryllium-copper 10, 25 and 165 alloys for electronic, automotive, appliance, instrument, temperature control and other applications is given in a new 12-page data-sheet series offered by the Pennrold Division of the Brush Beryllium Co., Reading, Pa. Chemical analysis, physical constants and mechanical properties of each alloy are described. Heat-treating procedures are outlined and illustrated. Working instructions are given for forming, joining, pickling, rolling and plating. Forms in which the alloys are available are also listed. The data-sheet series is illustrated by nine tables and four graphs.

For your free copy, circle No. 57 on Reader Information Card.

American Standards

The 1959 Price List and Index of American Standards, just published, is available from the American Standards Association, Dept PR 66, 70 East 45th St., New York 17, N. Y.

The publication lists the more than 1800 American standards approved to date by the American Standards Association. A standard is approved as an American Standard only if it is supported by a consensus of all national groups substantially concerned with its scope and provisions.

The fields covered by American standards include: automotive, chemical, civil engineering and construction, commercial standards; drawings, symbols and abbreviations; electrical engineering, ferrous materials and metallurgy, materials handling, mechanical engineering, mining, nonferrous materials and metallurgy nuclear, and industrial safety.

Also included in the publication are the international standards recommendations published by the International Organization for Standardization and the International Electrotechnical Commission.

For your free copy, circle No. 59 on Reader Information Card.

Stainless-steel Tubing

Technical data card TDC-192, published by the Tubular Products division of the Babcock & Wilcox Co., 161 E. 42nd St., New York, N. Y., describes the high-temperature properties of B&W Croloy 25-12, its chemical composition, size ranges, and short-time tensile and rupture properties.

For your free copy, circle No. 60 on Reader Information Card.

Hose Fittings

Details and illustrations of air, spray and welding-hose fittings for industrial rubber-hose applications are contained in "Le-Hi" Bulletin No. 198, recently issued by Hose Accessories Co., 2704 N. 17th St., Phila. 32, Pa. This four-page bulletin supplies complete information on the numerous types available.

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Current Welding LITERATURE

For copies of articles, write directly to publications in which they appear. A list of addresses is available on request.

Aircraft-engine Manufacture

Jet Pipe Welding Machine. *Welding & Metal Fabrication*, vol. 27, no. 5 (May 1959), pp. 202–203.

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Welding Repair of Aircraft Fuel Tanks, W. P. Campbell and M. J. Nolan. *Can. Metalworking*, vol. 22, no. 4 (April 1959), pp. 52–53.

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Design for Iowa Welded Steel Structures. *Better Roads*, vol. 29, no. 1 (Jan. 1959), p. 33.

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Electron Beam Welding—New Development for Industry, W. I. Steinkamp and W. L. Wyman. *Welding Engr.*, vol. 44, no. 4 (Apr. 1959), pp. 38–41.

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Automatic Electrical Welding of Cathode Ray Tubes. *Engineering*, vol. 186, no. 4833 (Oct. 24, 1958), pp. 554–555.

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Electro-Welding Replaces Forged Engine Components, R. L. Peterson. *Welding Engr.*, vol. 44, no. 4 (Apr. 1959), pp. 52–54.

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Multi-Station Welding—Money-Saver When Fabricating Modern Refineries, C. H. Voelker. *Welding Engr.*, vol. 44, no. 5 (May 1959), pp. 30–31.

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Here's How Bechtel Double-Joints Big Pipe, P. Reed. *Oil & Gas, J.*, vol. 57, no. 13 (Mar. 23, 1959), pp. 83–85.

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New Unit Solves Multiple Spot Welding Problems. *Welding Engr.*, vol. 44, no. 4 (Apr. 1959), pp. 90, 92.

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Ultrasonic Welding: Theory and Practice, J. R. Wirt. *Industry & Welding*, vol. 32, no. 4 (Apr. 1959), pp. 38–39.

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Extruded Uranium Welding Wire Proves Best, E. L. Brundige, G. S. Hanks and J. M. Taub. *Welding Engr.*, vol. 44, no. 5 (May 1959), p. 58.

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Fatigue Strength of Weld Metal, O. Eiro. *Engrs.' Digest*, vol. 20, no. 1 (Jan. 1959), pp. 45–47.

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Prediction in New Metal Joining Processes, J. J. Chyle. *SAE*—Paper no. 52S (for meeting Mar. 31–Apr. 3, 1959), 37 pp.

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Recent Developments in Weld Electrodes, W. P. Campbell. *Can. Metalworking*, vol. 22, no. 3 (Mar. 1959), pp. 40, 42–44, no. 4 (Apr.), pp. 58–60, 62-63.

Abstracts of Current PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D.C.

2,834,098—Metal-Arc Welding of 90-10 Type Copper-Nickel Material—George Raymond Pease, Westfield, and Theodore Ephraim Kihlgren, Berkeley Heights, N. J., assignors to the International Nickel Co., Inc., New York, N. Y., a corporation of Delaware.

This new article of manufacture covers a welded structure made from two members of a 90-10 type copper-nickel alloy containing about 5 to 15% nickel, 1 to 1.5% iron and the balance substantially all copper. Such members are joined together by a weld-metal deposit made from a specified composition and having a limited lead contamination therein not exceeding a specified percentage content of the silicon present in the weld.

2,834,101—Method of Brazing Titanium—Willard M. Boam, Fairlawn, N. J., Isidore Friedman, Brooklyn, Henry Paige, N. Y., and Leo Souzis, Brooklyn, N. Y., and Kurt Strater, Paterson, N. J., assignors to Curtiss-Wright Corp., a corporation of Delaware.

The present patent covers a method of bonding together two parts at least one of which is made from titanium. The method comprises the steps of immersing at least the surface of the titanium part to be bonded to the other part in a bath of boiling hydrochloric acid for at least ten minutes and, while still wet with hydrochloric acid, the part is connected to the negative side of an electric current. The said surface is immersed in a ferrous chloride bath and a very thin layer of iron is electroplated on such surface. Thereafter the parts are brazed together at a temperature of at least 1300° F.

2,834,870—Arc Welding Gun—William N. Platte, Boston, Pa., assignor to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

Platte's patent is on an arc welding gun to weld work in a shield of nonreactive gas. The gun includes a gun body having a channel to transmit gas and including means for supporting an electrode in welding relationship to the work. The gun is characterized by gettering means connected to the gun body at the terminus of the channel. The gettering means are connected to the arc so that during welding the gettering means are heated to a temperature such that it is effective in removing material such as water vapor, oxygen and nitrogen from the nonreactive gas.

2,834,871—Process for Manufacturing Welded Cast Iron Tubes by Electrical Resistance Welding—Manfred V. Berg, Gothenburg, Sweden.

This new method is for producing welded cast iron articles and comprises effecting current flow through pieces of cast iron by flash welding means. These cast iron pieces have a total percentage of carbon within the range of from 2.7 to 3.6% with a mutual variation in carbon content not exceeding 0.5% and containing more totally bound carbon than free graphite. In the process, the weld is rapidly cooled to a temperature of about 500° C and then slowly cooled from such temperature to room temperature.

2,834,917—Device for Starting and Stabilizing a Welding Arc—Jacques Moignet, La Frette, France, assignor to L'Air Liquide, Societe Anonyme pour 1'Etude et 1'Exploitation des Procedes Georges Claude, Paris, France.

Moignet's patent is on a pulse generating circuit to start and stabilize an alternating current welding arc. A first capacitor means is connected in series with a first gaseous discharge device and a second capacitor means is connected in series with a second gaseous discharge device that has a firing voltage other than that of the first discharge device. Means are provided to charge the capacitor means, and circuit means permanently connect both the members in parallel with the welding arc terminals.

2,835,783—Tube Welding Machine—Charles G. Watson, Youngstown, Ohio, assignor to the Youngstown Welding & Engineering Co., Youngstown, Ohio, a corporation of Ohio.

This apparatus for welding tubes included welding head support member of the size to fit within the tube to be welded and of the length as great as the length of the tube portion to be operated upon. Other means are provided to advance the tube along the path to telescope the tube about the support member, and a welding head is connected to such one end of the support member to weld the tube. Other means connect to the other end of the support member to mount it and the tube telescoped thereover for swinging movement to a discharge position defining an angle with the path.

2,835,784—Spark Machine Apparatus

2,835,785—Apparatus for Spark Machining—Everard M. Williams, Pittsburgh, Pa., assignor, by mesne assignments to Firth Sterling Inc., Pittsburgh, Pa., a corporation of Pennsylvania.

These patents cover new control circuits for electric spark machining actions.

2,835,786—Work Fabricating Machine—Ernie L. Launder, Montebello, Allen W. Loudon, Downey, and Max Frederick, Jr., Whittier, Calif., assignors, by mesne assignments, to H. & L. Tooth Co., Montebello, Calif., a corporation of California.

This machine is for welding around rectangular work parts having vertically disposed peripheral walls projecting from a horizontally disposed base. The machine includes a table mounted to reciprocate, and means to hold a work part on the table. An electrode is positioned to turn on a vertical axis and to reciprocate relative to the table. A welding rod is carried by the electrode with the rod terminal end intersecting the vertical axis and being adjacent the peripheral wall of the work part. An arc is established by weld means and the rod is fed so that the work part is welded while other means operate the table and electrode relative to each other so that the work part and arc move to establish straight predetermined lines of welding at the periphery of the work part.

2,835,864—Welded Control Apparatus—Andrew H. Decker and Arthur A. Meyer, Beloit, Wis., assignors to Warner Electric Brake & Clutch Co., South Beloit, Ill., a corporation of Illinois.

The patented control apparatus covers a combination of timing circuits to control the flow of welding current to a load circuit and operable to cause the welding current to flow in a succession of current on periods and then be followed by a period of no current flow. Variable impedance elements are provided in the timing circuits and means are provided to change the values of such impedance elements to vary both the length of current flow period, and the amount of current flow during such period.

2,835,965—Method of Welding—Wilbur H. Armacost, Scarsdale, N.Y., assignor to Combustion Engineering, Inc., New York, N.Y., a corporation of Delaware.

Armacost's welding method is for butt joining a pair of metallic tubes having a wall thickness between about 1½ in. and less than 3 in. First the wall thickness adjacent the ends of the tubes is reduced to less than 1½ in. and the ends are positioned in coaxial juxtaposed relationship. Thereafter the end surfaces are pressure welded at these reduced end portions and wire is wound under predetermined tension about the reduced portion of the ends throughout the axial length of the reduced end sections.

2,835,966—Medhod of Welding—Edward Corbin Chapman, Chattanooga, Tenn., assignor to Combustion Engineering, Inc., New York, N. Y., a corporation of Delaware.

This new method is similar to that described in Patent No. 2,835,965, but in this instance the tubes to be joined have a wall thickness of 1 in. or more so that a butt welded joint formed by a multilayer weld is likely to crack in service. Thus, first the wall thickness at the ends of the tubes is reduced to such a thickness that the cracking in service will not occur but with the reduction being not more than one-half of the original wall thickness. The end surfaces of these ends are positioned in coaxial relationship and they are welded together by a process involving building up the weld from multilayers of weld metal. Thereafter wire is wound under predetermined tension about the reduced diameter portion of the ends throughout the axial length thereof and to a radial extent sufficient so that weakening in hoop strength occasioned by the reduction in wall thickness is substantially more than offset by the wire strength added.

2,836,138—Machine for Brazing Seams—Irving F. Matthysse, Norwalk, and Christian V. Pellier, Westport, Conn., assignors to Burndy Engineering Co., Inc. a corporation of New York.

The present patent is on a specialized machine for manufacturing brazed articles including a tubular body and other special nontubular sections from a piece of sheet metal.

2,836,701—Method and Apparatus for Gas-Shielded Metal Arc Welding—Arthur A. Bernard, Chicago Heights, Ill.

The present novel method includes the steps of heating an electrode at a zone separated from the arc zone sufficiently to dehydrogenate same and at the same time directing the shielding gas over the surface of the electrode axially thereof in a turbulent flow to disperse the hydrogen into the shielding gas provided.

2,836,704—Arc Welding Machine—William Mason, Oakland, Calif., assignor to Independent Iron Works, Inc., Oakland, Calif., a corporation of California.

Mason's novel arc-welding machine includes a portable carriage support adapted to be carried directly on the work to be welded, and a carriage is provided that is movable along this support directly above the weld to be performed on the work. A pair of welding heads are carried by the support and positioned to extend downwardly and inwardly towards each other to points adjacent the work.

New Products

Horizontal Arc-welding Machines

A new line of eight horizontal-type "Sureweld" electric-arc-welding machines in the low and medium-price range has been announced by the National Cylinder Gas Division of Chemetron Corp., Chicago, Ill.

The compact new a-c and ac-dc welding machines feature comparatively high open-circuit voltages

which are said to give easy arc striking, excellent arc stability and faster welding. All models operate from single-phase a-c current.

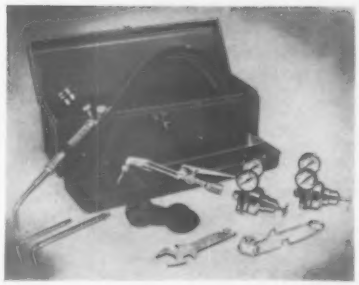
All models feature a movable core (shunt) design and a heavy-duty "on-off" switch conveniently located on the front of the control panel. This eliminates the use of plug-in type current controls and makes it unnecessary for the user to "pull the plug" to shut off the primary current when the welding operation is completed.

For details, circle No. 125 on Reader Information Card.

Welding and Cutting Outfit

A new moderately priced gas welding and cutting outfit, called the Aircomite, has been announced by Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y. With this new outfit, operators can weld steel up to $^3/_8$-in. thick, cut up to 1-in. steel plate, braze and hard face. It is built for light- and medium-duty industrial service.

The outfit includes one oxygen and one acetylene regulator, one welding torch with three tips, one cutting attachment and tip, one pressure mixer with gas sealing rings, a pair of welding goggles, $12^1/_2$ ft of $^3/_{16}$-in. neoprene-lined twin hose with connections, one spark-



lighter and one all-purpose wrench. It is packaged in a mechanic's metal carrying case.

Included with each Aircomite outfit is 32-page "How to Weld" booklet which describes, with illustrations, the preparation and techniques of welding, brazing, hard facing and cutting.

For details, circle No. 126 on Reader Information Card.

Goggle Respirator

A new full face combination goggle and respirator has been announced by the American Optical Co., Southbridge, Mass.

The new "Drednaut" features a one-piece, masklike goggle respirator combination molded from flexible rubber. An internally molded ridge separates the goggle section from the respirator section. A double facial seal results which stops exhaled air from reaching the goggle section.

The respirator section features a twin cartridge combination. Thirteen sets of cartridges and filters are available for protection against dusts, mists, fumes, gases, sprays, vapors, insecticides, radioactive particulate matter or combinations of these hazards.

For details, circle No. 128 on Reader Information Card.

High-temperature Alloys

Haynes Stellite Co., Division of Union Carbide Corp., 420 Lexington Ave., New York 17, N. Y., has announced the availability of several high-temperature alloys in wider cold-rolled thin-gage sheets than were previously available. Sheets

measuring 0.010 in. thick, 36 in. wide and 96 in. long are now being rolled as a result of recent refinements in technique at the company's expanding wrought alloy facilities in Kokomo, Ind.

Alloys currently available in this form are "Haynes" alloy No. 25, "Multimet" alloy, "Hastelloy" alloy R-235, "Hastelloy" alloy X and General Electric's "René 41" alloy. These alloys are among the leading materials in the field of high-temperature metallurgy.

For details, circle No. 129 on Reader Information Card.

AC-DC Welding Machine

A 250-amp ac-dc transformer-rectifier type welding machine, known as the "Big Twin," has been announced by the Miller Electric Mfg. Co., Inc., of Appleton, Wis. It has a-c ranges of 20–125 and 60–290; d-c spreads of 18–100 and 65–290. Rated output for both a-c and d-c is 250 amp at 30 v on 40% duty cycle or 200 amp at

40 v on 60% duty cycle.

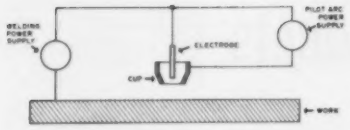
"Big Twin" operates from single-phase service for widest flexibility and maximum use. Current adjustments are possible using a movable shunt-type transformer and incorporation of semimetallic rectifier stack is said to qualify this welding machine for production line requirements. Compact size (only 25½ in. high) and instant selection between a-c and d-c straight or reverse polarity suits the "Big Twin" for the varying demands of the average job shop. Power factor correction is also available (optional).

For details, circle No. 130 on Reader Information Card.

Pilot Arc

A development of Linde Co., Division of Union Carbide Corp., 420 Lexington Ave., New York 17, N. Y., called "Pilot Arc" is said to result in positive arc starting for inert-gas tungsten-arc spot welding or cutting.

Utilizing a principle much like the pilot light in a gas stove, it is claimed that "Pilot Arc" eliminates problems involved in conventional high-frequency starting, increases



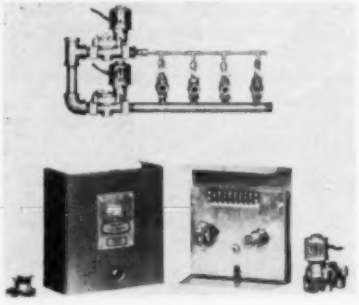
electrode life and process reliability.

Applications where the new technique is particularly useful include mechanized installations where torches must be fired according to a predetermined schedule, and high-speed production setups.

For details, circle No. 131 on Reader Information Card.

Water Saver

A low-cost water-saving control for resistance-welding machines is being marketed by Van Vooren Products, East Moline, Ill. Featuring a short proportioning time delay, solenoid valve and thermostatic control, it is said to pay for itself in water savings. Known as



the "Water Mizer," the control can result in significant economies on large scale operations.

For details, circle No. 132 on Reader Information Card.

Semiautomatic Welding Machine

American Manganese Steel Division, 389 E. 14th St., Chicago Heights, Ill., announces a new, completely redesigned semiautomatic welding machine for hard surfacing in the shop or in the field. The manufacturers state that the machine is light and portable, extremely simple and reliable in operation and maintenance. It is used to build up dipper teeth, dipper lips, crusher rolls and hundreds of other parts that cannot be hard faced with fully automatic equipment.

The Amsco semiautomatic welding machine is connected to any 300 amp or larger d-c power source and feeds hard-surfacing wire through a hand-held electrode holder whenever the holder switch is depressed. The holder switch also gives remote inching control as required. It is very easy to move

around because of its "golf-cart" construction and large wheels.

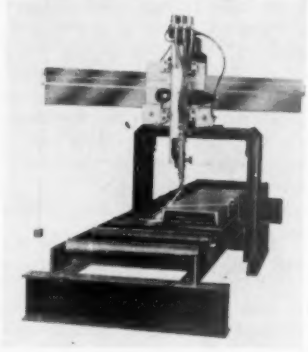
The machine is completely enclosed to avoid shock hazards, and to protect the reel of wire. Hard-surfacing or build up material can be laid on continuously at a very high rate without the waste of time or material normally required when using stick electrodes.

For details, circle No. 135 on Reader Information card.

Shape Cutter

Steffan Manufacturing Corp. of Salem, Ohio, announces that its new "Structural Shape Cutter" is now available to the market.

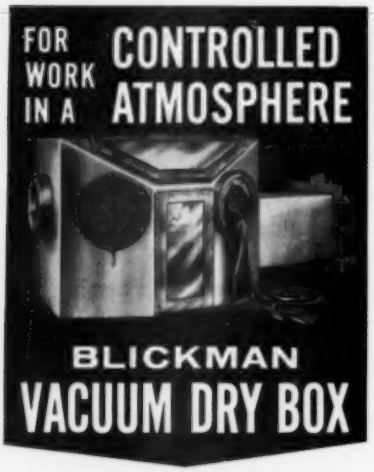
The structural shape cutter employs engineering features which are said to reduce handling, layout and cutting time on structural shapes such as I-beams, H-beams, angles, channels, bars and plates.



Two independently operated variable-speed motors activate the horizontal and vertical geared tracks. Other features are solenoid valves which coordinate the gas and oxygen at the burning tip and an adjustable dial that can be set allowing smooth, mitered or straight cuts. A roller-conveyor with magnetic holding device is also included.

Structural shape cutters are available in the following stock-cutting sizes: 24 in., 36 in. and 48 in.

For details, circle No. 133 on Reader Information Card.



Designs and specifications are available for a variety of welding enclosures for research and production welding, and for work in the fields of metallurgy and physical chemistry. These enclosures can be fully evacuated and then be filled with an inert gas for welding in an inert atmosphere. Write for Technical Bulletins on various types of welding enclosures: S. Blickman, Inc., 3008 Gregory Avenue, Weehawken, N. J.

BLICKMAN
LABORATORY EQUIPMENT

Look for this symbol of quality Blickman-Built

For details, circle No. 36 on Reader Information Card

In this versatile welder, Vickers has combined:

1. Standard Arc Welding
2. Constant Potential Welding
3. Tungsten Inert Gas Welding

in ONE Outstanding Machine.

The price is less than half of separate machines!

And this combination has been achieved *with no loss of complete welding performance*. Standard or CP operation is superior to operation of competitive individual machines. Now you can do almost any welding job from this single source, without an expensive investment in multiple machines.

NEW—From Vickers . . . 500 Amp. Constant Potential Welder

Can be paralleled to give any current for any semi-automatic or automatic job requiring direct current constant potential power.

- Built in remote control receptacle.
- Voltage adjustable (stepless) from approx. 13 to 36 volts.
- Slightly falling output slope—may be adjusted internally to flat or slightly rising for special conditions.
- Hot start adjustable. May be internally adjusted to any desirable degree.
- High speed of response.
- No moving parts.
- Quickly paralleled for high output requirements.

■ Contact our nearest welder dealer for prices or call factory!

■ Write for special descriptive bulletins 7136-1 and 7146-1.

EPA 7110-2

ELECTRIC PRODUCTS DIVISION VICKERS

VICKERS INCORPORATED
DIVISION OF SPERRY RAND CORPORATION
ELECTRIC PRODUCTS DIVISION
1853 LOCUST STREET • SAINT LOUIS 3, MISSOURI

For details, circle No. 19 on Reader Information Card

Heavy-duty Work Positioner

Boesch Manufacturing Co. of Danbury, Conn., has announced that it has developed the new PM-1051 Work Positioner. It will handle weldments weighing as much as 2000 lb, and its 32-in. table (42 in. optional) has six milled tee slots for jigs or fixtures to accommodate a wide variety of shapes.

The table tilts from "work vertical" position to "work 15-deg below horizontal" position. The desired tilt angle is set on the protractor, and the tilt button on the operator's control panel is depressed for momentary contact. The table stops automatically when the work reaches the preselected position.

The table rotates through the full 360 deg in either direction. Rotation speed may be varied continuously from 0 to 4 rpm. A worm and gear drive, mounted on ball bearings and immersed in oil, transmits the rotation power without vibration.

For details, circle No. 136 on Reader Information Card.

Resistance-soldering Tool

General Electric Co., Schenectady 5, N. Y., has developed a new resistance-soldering tool to eliminate arcing and to provide 5-speed, void-free connections in the aircraft and missile industries. The unit consists of the transformer, a hand tool that has a pressure-operated switch and a single zirconium-tungsten electrode. The transformer is rated 400-v amp with provision for 2 heats. The tool is automatic, particularly adaptable to soldering multiple-prong plugs.

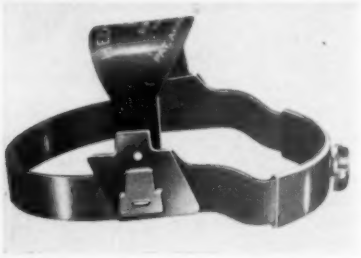
According to the manufacturer, the electrode does not require frequent redressing, maintenance or replacement due to burn-down, and the tip can be ground to a shape that conforms to the pin shape.

For details, circle No. 137 on Reader Information Card.

Adjustable Headgear

Designed to conform to any head size, a new Cesco Hed-Rite Headgear adjusts three ways: for head size; for over-all strap length; for overhead strap position.

Rear knob provides head-size adjustment by ratchet action and wide cross strap pivots freely back and forth. Four holes in each end of the strap permit positioning strap length so as to conform to any crown height or head contour. Headband is designed to produce the broad contacts necessary for complete comfort.



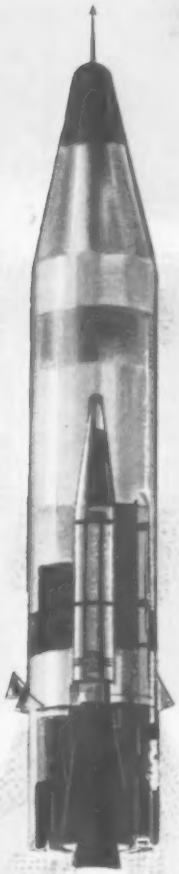
Cesco says that their new headgear can be worn with any face shield, helmet, hood or goggle equipped with Cesco X-14 brackets.

For details, circle No. 138 on Reader Information Card.

Measuring Instrument for Nonmagnetic Metals

A new portable eddy current instrument has recently been added to the group of testing systems available from Magnaflux Corp., 7300 W. Lawrence Ave., Chicago 31, Ill. By accurately measuring electrical conductivity, the battery-powered "Magnatest FM-110 Conductivity Meter" performs a variety of testing jobs, including the determination of hardness, alloy and heat treat condition; sorting mixed nonmagnetic metals; checking tensile strength of aluminum; investigating fire damage to aircraft; and many others.

BRIGHT FINISH
ALUMINUM
WELDING WIRE
☐ deposits uniformly
☐ eliminates interruptions
☐ makes x-ray quality welds
All-State Bright Wire Spoolarc, extruded and precision spooled, is uniformly round, microscopically clean . . . meets aviation, tankage, and shipbuilding standards.
Send for booklet and chart on all types and forms of aluminum in BRIGHT FINISH . . . including 1 lb. and 10 lb. spools. Stock maintained at St. Louis, South Gate, Calif., Toronto, Canada, and White Plains, N. Y.
Distributor-Stocked, convenient to buy. Economical to use.
ALL-STATE WELDING ALLOYS CO., INC., White Plains, N. Y.
Call WHite Plains 8-4646 or write for nearest distributor
For details, circle No. 20 on Reader Information Card



FIRST programmed automation for inert gas welding!

FIRST tape-controlled programming!

Once again P&H sets the pace in welding progress! This time it's equipment for programmed welding.

The new P&H motorized rheostat control brings automation to the welding of Space Age and other super-critical metals. Now you simply dial pre-calculated heat-time values for each job, press the start button, and the control furnishes the exact cycles needed for controlled "upslope", welding cycle, and decay.

And for automated welding at its modern best, P&H offer you exclusive punched-tape control—enabling you to program and control a wide range of heat-time cycles. You can store tapes for re-use —to speed welding and to standardize welding quality at levels far above those possible with human control!

Interested? Contact P&H *now* for additional information. Write Dept. 307C, Harnischfeger Corp., Milwaukee 46, Wisconsin.

P&H HARNISCHFEGER
WELDERS · ELECTRODES · POSITIONERS

NEW welding FIRSTS from P&H

For Spot-Gun or Automatic Welding
with built-in controls.

Automatic Spot-Gun Work
with controls atop the welder or at the work.

P&H Tape-Programming
completely automates the fusion process—gives control over welding impossible by manual methods.

P&H Motorized Rheostat
for precise control of heat stages to prevent thermal shock and cracking.

For details, circle No. 21 on Reader Information Card

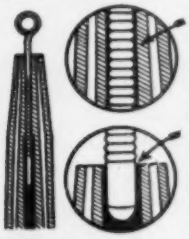
World's Finest CUTTING and WELDING TIP CLEANERS

WYPO
WIPES AND POLISHES

YOU GET SO MUCH MORE IN WYPO
Made of Stainless Steel

DOUBLES THE LIFE OF YOUR WELDING AND CUTTING TIPS

The exclusive circle design found only in Wypo Cutting and Welding Tip Cleaners provides as many as 60 more cleaning edges per inch of cleaner.



These rounded outer edges of cleaning ridges clean and polish tip orifice without scratching or cutting.

This smooth pilot guides WYPO Tip Cleaner into tip Will not enlarge or damage tip port.

This cross section view of WYPO Cleaning Surfaces shows these exclusive features:

Rounded cleaning surfaces that won't jam or cut.

Straight sided valleys insure thoro cleaning by removing all waste.

SPRING LOADED SPOOL

Spring loaded brass spool. Will not rust. Holds cleaners securely in case.

DOUBLE WOUND EYES

Insures longer life for small sizes of WYPO Tip Cleaners. Will not pull out of case.

NOW AVAILABLE IN 3 CONVENIENT SETS

WYPO TIP CLEANERS STANDARD SET

CLEANER NO.	FOR DRILL
7	75-74
8	73-72-71
10	70-69-68
12	67-66-65
14	64-63-62
15	61-60
16	59-58
17	57
18	56
22	55-54
24	53-52
26	51-50-49

MADE IN U.S.A.
PAT NOS 2609561, 2673750 AND CANADA 1948

WYPO TIP CLEANERS JUMBO SET

CLEANER NO.	FOR DRILL
28	48-47
30	46-45
33	44-43
36	42-41
37	40-39-38
39	37-36
42	35-34-33
44	32
44	32-31
45	30

MADE IN U.S.A.
PAT NOS 2609561, 2673750 IN CANADA 1948

MASTER SET

CLEANER NO.	FOR DRILL
7	75-74
8	73-72-71
10	70-69-68
12	67-66-65
14	64-63-62
15	61-60
16	59-58
17	57
18	56
22	55-54
24	53-52
26	51-50-49
28	48-47
30	46-45
33	44-43
36	42-41
37	40-39-38
39	37-36
42	35-34-33
44	32-31
45	30

MADE IN U.S.A.
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WYPO TIP CLEANERS

STANDARD SET OF (12) Cleans (37) Drill Sizes Nos. 75 to 49 Incl.

JUMBO SET OF (9) Cleans (19) Drill Sizes Nos. 48 to 30 Incl.

MASTER SET OF (21) Cleans (46) Drill Sizes Nos. 75 to 30 Incl.

Replacement cleaners available. Cleaning Range —Cleaner No. & Drill Nos. stamped on back of each case. WYPO GIVES YOU MORE!

SOLD BY LEADING WELDING SUPPLY DEALERS

MAITLEN AND BENSON, INC.
1395 Obispo St. Long Beach 4, Calif.

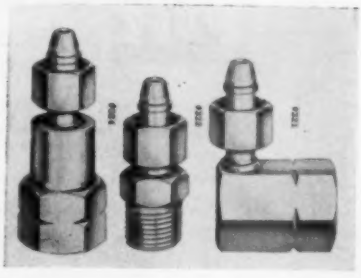
For details, circle No. 22 on Reader Information Card

The FM-110 induces eddy currents within the test piece by means of a $^1/_2$-in. diam hand-held probe. These currents affect the impedance of the probe coil as a function of the conductivity of the material. With the probe on one side of the test piece, the large knob is turned to zero the meter and conductivity is read on the left-hand scale.

For details, circle No. 139 on Reader Information Card.

Brass Adaptors

Western Enterprises, Inc., Bay Village, Ohio, manufacturer of brass fittings for the welding trade, has announced three new additions to their adaptor line.



Adaptor No. 321 adapts "MC" Tank to P. O. L. Acetylene Regulator; Adaptor No. 322 adapts "MC" Tank to Commercial Acetylene Regulator; and Adaptor No. 324 adapts "MC" Tank to P. O. L. Acetylene Regulator.

For details, circle No. 140 on Reader Information Card.

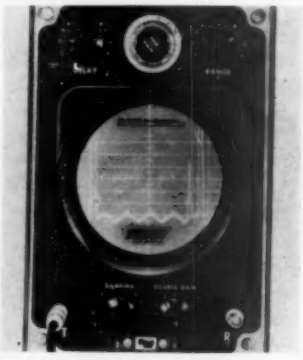
Resistance-welding Machine

Peer, Inc., 1220 Milton St., Benton Harbor, Mich., has developed a resistance butt-welding machine for shop use and light production applications. Known as Model B-1, the unit is recommended for various applications such as lengthening of screws, pins and rods, and for joining the ends of saw blades and metal bands. It is also recommended to join the end of one reel of wire to another where a continuous-wire production process is involved.

For details, circle No. 101 on Reader Information Card.

Ultrasonic Testing

Branson Instruments, Inc., 40 Brown House Rd., Stamford, Conn., has announced a new ultrasonic-testing unit, the Sonoray Model 5. The 35-lb portable unit is said to adjust automatically to any transducer within its 0.4- to 10-mc operating range. The inherent pulse-echo detection principle permits detection of flaws and measurement of thicknesses. Calibrated fine and coarse-grain adjustments reportedly provide amplification range of more than 25,000 to 1. The instrument operates on 110 v, 60-cycle current and draws 160 w.

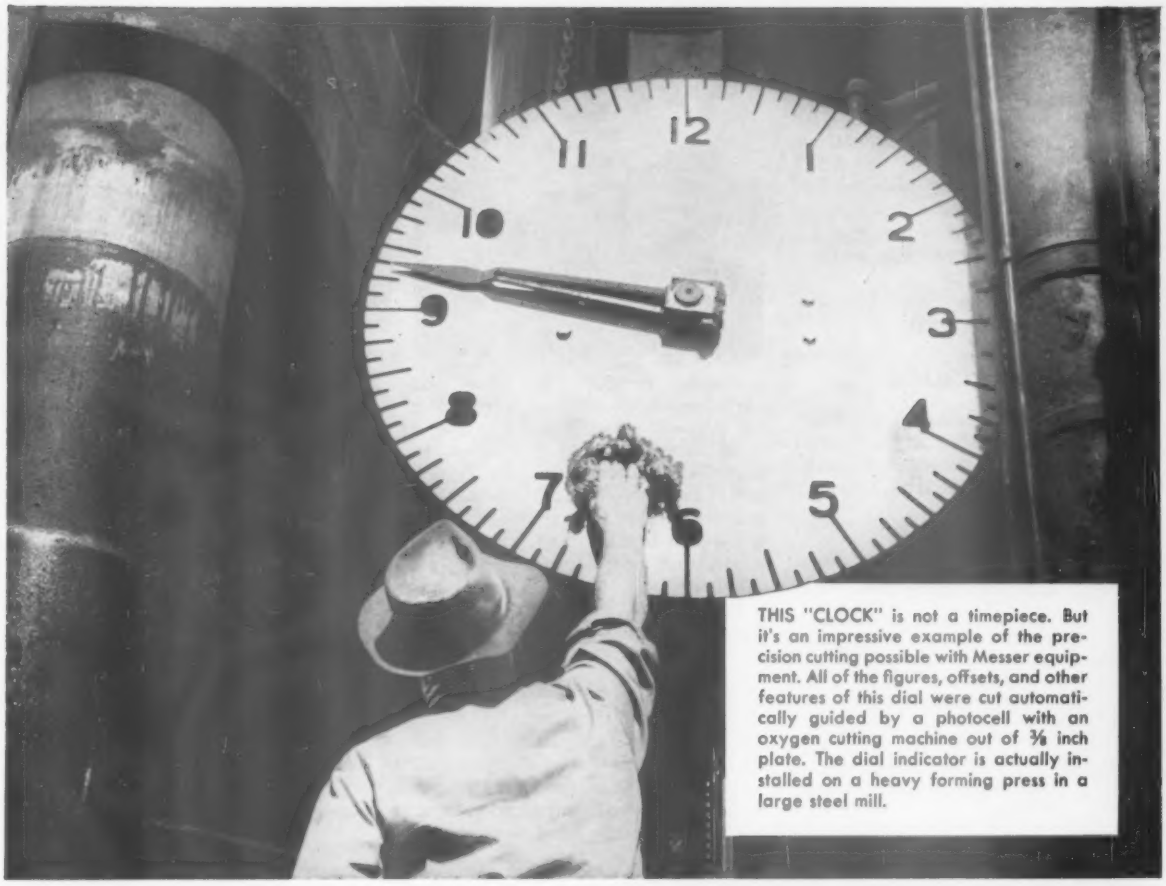


For details, circle No. 102 on Reader Information Card.

Fork-lift Truck Attachment

A new materials handling device known as the "automatic safety lock fork-lift attachment," is now available from Merrill Brothers, Maspeth, Long Island, N. Y., to simplify transporting heavy loads, such as dies or motors.

It is made entirely of forgings, in-



THIS "CLOCK" is not a timepiece. But it's an impressive example of the precision cutting possible with Messer equipment. All of the figures, offsets, and other features of this dial were cut automatically guided by a photocell with an oxygen cutting machine out of ⅜ inch plate. The dial indicator is actually installed on a heavy forming press in a large steel mill.

Around the clock...

MESSER CUTTING MACHINES PERFORM NEW MIRACLES IN AUTOMATIC PRECISION CUTTING

Isn't it "time" you thought about the money-saving advantages you can get through the use of the new and revolutionary cutting techniques now possible with *Messer Cutting Machines*?

INCREASE YOUR PROFITS

Experience has shown that the Messer cutting machine versatility of design permits greater shop flexibility and the increased use of automation. The result? Lower costs, lower waste, GREATER PROFITS.

This unique oxygen cutting equipment features a completely engineered system of operation. This leads to new high standards in precision workmanship and greater accuracy.

ASK US FOR MORE DETAILS!

In steel mills, in shipyards—wherever cutting machines are used—Messer equipment can increase efficiency. It will pay you to find out now what Messer can offer you. Write us for full information. No obligation, of course. Messer Cutting Machines, Inc., Chrysler Building, 405 Lexington Avenue, New York 17, N.Y.

Messer Cutting Machines

WELDING ENGINEERING SINCE 1898

For details, circle No. 24 on Reader Information Card

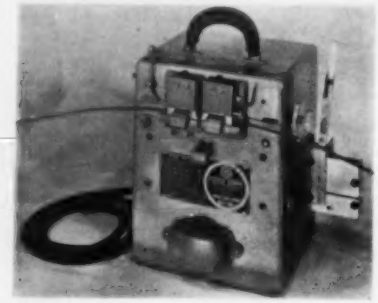
cluding a safety swivel hook. When slipped onto the forks (no wrenches, no adjustments), two knife-edged levers grip the forks tightly as the load is applied, but can be slipped off when the load is released.

They are especially designed to transform any fork-lift truck into a safe, efficient, mobile overhead lifting unit, thus adding to the usefulness of fork-lift trucks.

For details, circle No. 104 on Reader Information Card.

Band-saw Welding Machine

An improved band-saw welding machine, which welds up to $^3/_4$-in. blade widths, has been introduced by Rockwell Manufacturing Co.'s



Power Tool Divisions, 454 N. Lexington Ave., Pittsburgh 8, Pa.

The revised model features a factory-set flash adjustment and improved jaw-clamping adjustment, tension adjustment and blade-width indicator.

Designed for manufacturing operations that require large quantities of band-saw blades, the unit will reportedly cut and weld any length blade. The unit also features a blade shear and a grinding wheel for removing flash.

For details, circle No. 105 on Reader Information Card.

Automotive Welding

Progressive Welder Sales Co.'s Special Machinery Division, Pontiac, Mich., has completed a three-station, three-headed automatic arc-welding machine, designed to weld the parking gear to the carrier-case assembly in automobile transmissions—a job previously done by rivets. This new machine handles 180 pieces per hour when operating at 80% efficiency.

At Station 1 the parking gear is placed on a set of locating pins. The carrier fits over a cam locator on the parking gear. The machine moves the parts to Station 2 where the joint to be welded is induction

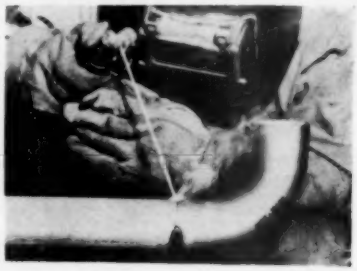
preheated to 550° F. Then the parts move to Station 3 where a lift cylinder raises them up into a head assembly which rotates to make the three necessary welds simultaneously. The finished piece indexes back to its original position, is lowered to the transfer rails and is shuttled out to the customer's conveyor.

For details, circle No. 107 on Reader Information Card.

Stainless-steel Fittings and Flanges

Tube Turns Division of Chemetron Corp., Louisville, Ky., has introduced a new line of light-wall stainless-steel fittings and flanges designed for nominal-temperature, low-pressure noncritical process piping.

The new line, called "Pipe-Mate," will be stocked in $^1/_2$ through 4-in. sizes, Schedule 5S and 10S, in the stainless-steel grades reportedly best suited to corrosive applications in the large middleground area of roughly 150 psi or less.



A special feature is a swivel-type insert flange designed for ease of alignment. It is a carbon-steel flange, and it has a stainless-steel insert at the bore into which pipe or fitting can be expanded, then the carbon-steel portion is simply rotated to line up the bolt holes and tightened. No welding is involved. Another feature of the new line is a reversible fitting called the "Plug-R-Cap." Butt welded in regular position it is a cap. Reversed, it can be fillet welded easily to act as a plug or pipe closure.

Pipe-Mate stainless-steel fittings can be butt welded in the normal manner or, with the use of an alignment connector or sleeve, they can be fillet welded or brazed. Where flanged connections are desired, the pipe or fittings are simply expanded into the bore of the flange insert and no welding is required.

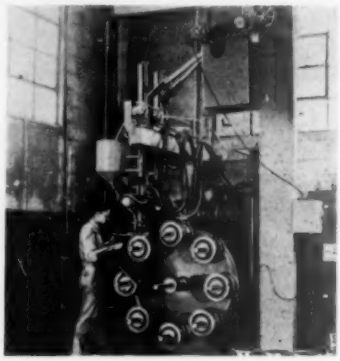
Both expanders and alignment connectors will be included in Tube Turns' light-wall Pipe-Mate line, in addition to 45- and 90-deg elbows, returns, eccentric and concentric reducers, tees and crosses, reducing tees, caps, stub ends, flared nipples and flanges.

For details, circle No. 108 on Reader Information Card.

Tractor-roller Rebuilding

The Sight Feed Generator Co., West Alexandria, Ohio, has designed a new Rexarc "Automatic Flux Circulating System" and the model MS-8 "Dual Heat Automatic Roller Rebuilder" into a combination product known as "Rexarc Twins."

The flux system reportedly provides automatic handling of flux in a process that separates unfused flux.



The rebuilder itself contains eight spindles and will index from one roller to the next within seconds. According to the manufacturer, by the time the first welded roller reaches the eighth index position, it has cooled sufficiently to take the second welding pass.

For details, circle No. 110 on Reader Information Card.

X-ray Unit

The Baltograph 180, Panoram-x, a new industrial X-ray unit designed for a variety of radiographic inspection of pipe and tank welds, castings, assemblies and steel structural work has been announced by Balteau Electric Corp., 25 New St., Stamford, Conn.

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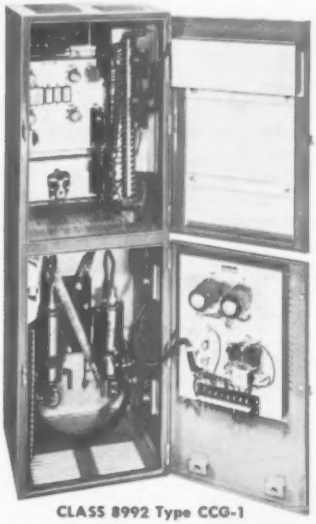

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The essential feature of the unit is the 180-kvp, 5-ma X-ray head, reportedly capable of 360-deg. internal radiography as well as examination of circumferentially arranged "outside" work and spot or single beam use. A leaded removable diaphragm around the X-ray tube permits this variety of application.

Weighing 111 lb and measuring 40½ in. long by 11⅝ in. in diam with handles, the head is gas insulated, inherent filtration is low and penetration capability is up to and including 2⅜-in. steel.

The control unit is a weatherproof cabinet, incorporating a penetration meter and selector, MA control, push-button powered automatic reset timer and guarded receptacles. Weight is 41 lb. Dimensions: 15 x 12 x 7 in.

For details, circle No. 111 on Reader Information Card.

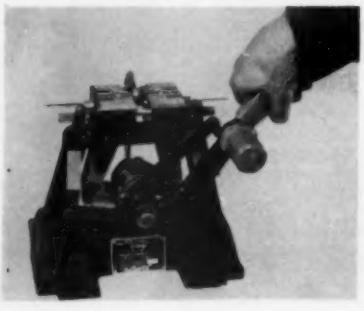
Cold Pressure Welding

A hand-operated bench model tool, Model KBM-1, for cold pressure welding has been announced by Koldweld Division, the Kelsey-Hayes Co., Utica 4, N. Y. The new tool requires no current, heat or fluxes.

The unit will handle from No. 18 to No. 8 AWG aluminum wire and from No. 18 to No. 9 AWG copper wire.

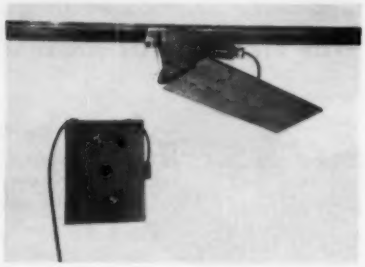
In addition to aluminum and copper and their alloys, some brasses, lead, zinc, nickel, silver, palladium, platinum, gold and tantalum wires have been butt welded to themselves and each other. Formex and enamel coated wire reportedly can be welded without removal of coating.

For details, circle No. 113 on Reader Information Card.



Permanent Magnet

A permanent magnet with electric shutoff, known as Dual-Mag, has been developed by Storch Products Co., Inc., 9232 Greenfield, Detroit 28, Mich. Capable of holding 175 lb. when the current is off, the device releases the part when the current is on and can be converted into an electromagnet with 600-lb holding power.



For details, circle No. 114 on Reader Information Card.

Cutting Nozzles

A new selection of oxygen-cutting nozzles for use with acetylene or fuel gas has been introduced by Linde Co., Division of Union Carbide Corp., 30 E 42nd St., New York 17, N. Y. Included in the new selection are bendable nozzles for riser removal, and nozzles for fin washing, general-duty cutting and high-speed mechanized shape cutting.

Each of the new two-piece Oxweld nozzles, series 1534 and 1535, has from 12 to 20 small outlets for preheat gases. Cutting speeds are reportedly increased by a divergent nozzle bore design that increases by 20% the speed of the gas leaving the nozzle.

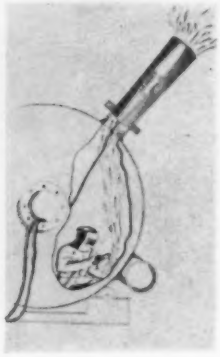
Rates of metal removal of fin-washing operations are said to be doubled with new Oxweld 1523 and 1524 series nozzles.

Bendable nozzles for riser removal and cutting in remote spots are also included in the new selection. Known as the 1540 series, these 10-in. long nozzles have 10 preheat outlets and are for use with natural gas, propane and other fuel gases.

For details, circle No. 115 on Reader Information Card.

Exhaust for Welding Fumes

Equipment to exhaust welding fumes from closed welding areas has been developed by Arcair Co., Lancaster, Ohio. Called the "Air Mover," the device is powered by ordinary compressed air from the shop line, directing stale air out and drawing fresh air in. The manufacturer reports low noise level during operation.



For details, circle No. 116 on Reader Information Card.

Electron-beam Welding Machine

An electron-beam welding machine has been announced by NRC Equipment Corp., 160 Charlemont St., Newton 61, Mass. The new unit is designed for laboratory and production welding or reactive metals which are best joined in a high vacuum and of thin sections of more common materials such as stainless steel.

Welding is accomplished by directing a beam of high-energy electrons on the work from a special NRC gun positioned at the top of the welding chamber.

For normal operation, the work is set up on the table, the chamber is evacuated and the electron gun is turned on. The operator focuses the beam and, for a straight weld, manually moves the work along the longitudinal axis. Beam current is 0–100 ma at 0–10 kv or 0–20 kv, depending on the rating of the gun that is supplied.

Actual maximum welding speed of the Model 2770 electron-beam welding machine is ½ in. per sec

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Working with AWS technical committees in gathering and correlating technical data; preparing minutes, reports and other records of committee activities; editing standards for publication as completed.

Disseminating technical information in answer to inquiries from industry.

Related duties as assigned.

Here are the qualifications—

Ability to work with technical men at all levels in a cooperative manner. This is necessary to deal successfully with committee personnel, AWS members and the general public.

A degree in engineering, any branch.

At least three years' experience in engineering work, preferably in welding or allied fields.

Here is an opportunity—

The man we are seeking has initiative and imagination and is interested in becoming familiar with welding in all its aspects and for every type of application. Salary will be commensurate with qualifications and experience.

If interested in being interviewed for this position, send a resume* of your education, experience and personal background to

Technical Secretary
American Welding Society
33 West 39th Street
New York 18, N. Y.

* Will be held confidential.

longitudinally, while circular welds can be made at 5 rpm. Circular welds up to 8-in. diam and longitudinal welds up to 4 in. long can be made without modifying the unit.

For details, circle No. 142 on Reader Information Card.

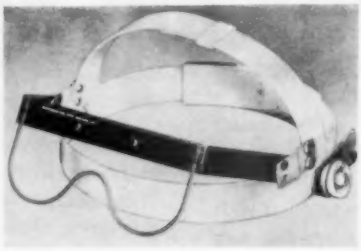
Protective Film for Metals

Chemical Consulting Service, 3701 S. Clement Ave., Milwaukee 7, Wis., has developed a plastic emulsion which, when dry, gives a transparent, tough film to protect smooth and wrinkled metal finishes, stainless-steel and polished aluminum surfaces during manufacture, storage and transit. Applicable by brush or spray, the product, called Strip-Kote, will cover 500 sq ft/gal for 0.004 in.

For details, circle No. 118 on Reader Information Card.

Welding Headgear

The Huntsman "welding headgear" is now molded of the new rigid polyethylene. This material is tough without being brittle, yet readily conforms to the shape of the wearer's head. The headgear, a product of the Kedman Co., Salt



Lake City, Utah, has a positive locking knob adjustment. The ball-bearing locking device has "controlled tension" which forms the part of the linkage between the headgear and the welding helmet shell that positions the filter plate directly in the line of vision when welding, and holds the helmet over the head while the welder is preparing his work.

For details, circle No. 119 on Reader Information Card.

Mobile Gun Unit

A mobile gun unit, recently developed by the Federal Machine and Welder Co., Warren, Ohio, for general purpose portable spot welding of parts, features a lightweight welded steel cart for ease in moving the unit from one weld

position to another. The welding transformer, heat regulator, electronic controls, air controls, air valve and flexible cables with air-operated gun, are all mounted on the cart.

For details, circle No. 120 on Reader Information Card.

Carbon-graphite Electrode

A new cutting electrode called Keen-Cut by its manufacturer, Becker Brothers Carbon Co., 3450 S. Laramie Ave., Cicero 50, Ill., is available for carbon arc-air jet cutting and gouging work.

The Keen-Cut electrode is designed to maintain maximum current capacity with minimum current consumption. Manufacturer claims an easy-starting, hot, stable cutting arc with accuracy controllable to a high degree. Smoke and gases are said to be eliminated and the resulting surface gouge is left smooth and slag-free.

"Keen-Cut" electrodes are available black or copper-coated, 12-in. lengths, in all standard diameters for operation in the 150- to 1400-amp range.

For details, circle No. 143 on Reader Information Card.

E6012 Electrode

Hobart Brothers Co., Troy, Ohio, have developed Hobart 12A, a new E6012 electrode with iron powder added to the covering. To be used in all-position welding of mild steel, the electrode was designed principally to increase deposition rates. It reportedly operates better on d-c straight polarity, but good results can be obtained with alternating current.

Available in $^1/_8$ and $^5/_{32}$ in. diam in 14-in. lengths, $^3/_{16}$ in. in 15-in. lengths and $^7/_{32}$, $^1/_4$–$^5/_{16}$ in. diam. in 18 in., the electrodes are packed in 50-lb containers.

For more details, circle No. 99 on Reader Information Card.

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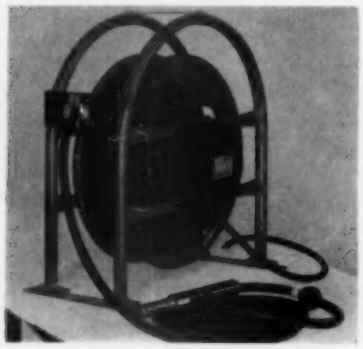
For details, circle No. 32 on Reader Information Card

Cable Reel

A new self-retracting reel for welding cable has been introduced by United Specialties Inc., El Dorado, Ark. Designed to hold 50 ft of 2/0 cable, it has current capacity of 30 amp with 60% overoad factor. The new reel, des-



ignated as Weldreel Model EA2, is equipped with a heavy-duty retracting spring. The unit can be mounted on walls, floors, ceilings or mobile equipment.

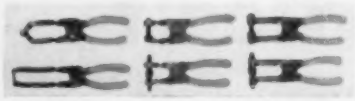
The reel is 23 in. long, 12 in. wide and $22^1/_2$ in. high. Without cable the reel weighs 64 lb.

For details, circle No. 148 on Reader Information Card.

Flexible Toggle Clamps

Flex-o-matics, new series of flexible toggle clamps, have just been announced by Detroit Stamping Co., Midland Ave., Detroit 3, Mich.

These new clamps are die cut and formed from high-carbon steel. Stainless-steel rivets are fitted into burnished pivot holes.



The new series consists of six models, four of which feature tempered flat spring-action jaws to provide for automatic compensation of material thicknesses from preset dimension to a recommended additional $^3/_8$-in. jaw gap.

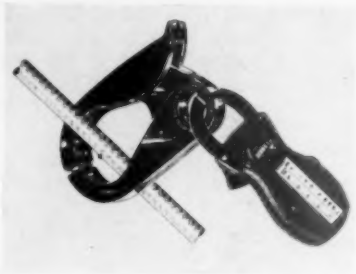
Two of these four models, the 420 and 421, have preset 0-in. jaw gap, requiring no adjustment spindle. The other two, 421-1 and 421-2, combine automatically adjusting flat spring-action with standard De-Sta-Co screw-type spindle assemblies.

The other two models, the 431-1 and 431-2, do not have the feature of automatic compensation for material thicknesses, but provide conventional clamping action with up to 350-lb holding pressure.

For details, circle No. 149 on Reader Information Card.

Current-reading Instrument

The Amprobe "Deca-tran," manufactured by the Pyramid Instrument Corporation, 630 Merrick Road, Lynbrook, N. Y., is designed primarily for use with any Amprobe where an extension of ranges is needed.



A feature of the Amprobe "Deca-tran" reportedly realized accurate readings on conductors as large as $2^1/_{16}$-in. rounds and $^3/_4 \times 2^1/_2$-in. bus bars at the conductor or at a distance of two feet.

For details, circle No. 150 on Reader Information Card.

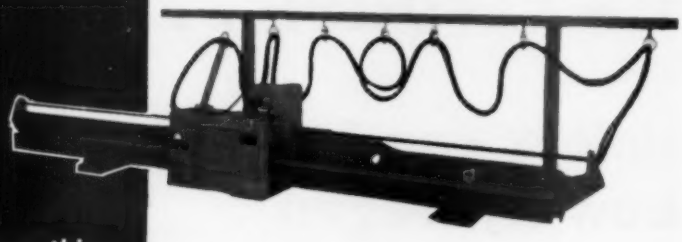
Soldering Kit

The "Kwik-Kit," containing an assortment of wires and fluxes for hard and soft soldering, is available from Special Chemicals Corp., Ossining, N. Y.

Recommended for most maintenance jobs, the materials within the

kit can be used to solder such metals as steel, stainless steel, copper, bronze, beryllium copper, platinum, gold, silver alloys, nickel and Monel. They are not suitable for joining aluminum, magnesium or titanium.

For details, circle No. 141 on Reader Information Card.



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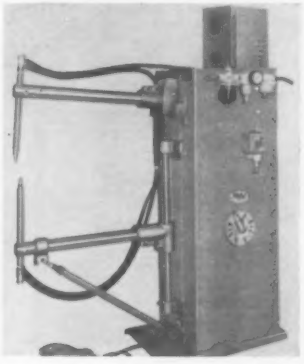
For details, circle No. 39 on Reader Information Card

Resistance-welding Machine

An air-operated rocker-arm type resistance-welding machine, available in capacities from 7½ to 75 kva, has been announced by Alphil Spot Welder Mfg. Corp., 1058 Pacific St., Brooklyn 38, N. Y.

The unit is equipped with such features as heavy-duty heat selector with full load capacity, rear switch rod, contact assembly, air cylinder, standard electrode holders, electrodes and morse tapers. Water cooled, the standard model has a maximum spacing of 12 in. between the arms with special models available for 48-in. throat depth and adjustable lower swivel arm having a maximum spacing of 28 in. between the arms.



For details, circle No. 121 on Reader Information Card.

Ultrasonic Testing

Ultrasonic Testing and Research Laboratory, 14710 Raymer St., Van Nuys, Calif., has announced a new ultrasonic recording system for bond testing and flaw detection. The "Soltronics Sonfax" system results in a permanent record of test information which places, on a practical basis, the ultrasonic inspection of brazed joints and adhesive bonded structures. Excellent sensitivity and definition are reportedly obtained from tests of facing sheet to core bond in brazed honeycomb. With the system, one-to-one scale recordings can be made of areas 18 in. wide and of indefinite length.

For details, circle No. 117 on Reader Information Card.

Rain Hood

A rain hood is being manufactured by the Fibre-Metal products Co., Chester, Pa.

Designated Rain Hood R-1, it installs in Fibre-Metal's line of fiberglass and aluminum hats and caps. There are only four points of attachment to the headband and three plastic fasteners at its front.

For details, circle No. 124 on Reader Information Card.

Safety Glasses

Sellstrom Manufacturing Co., Palatine, Ill., has introduced Series 711 "Duo-Tone" plastic-frame safety glasses which the firm claims to be outstanding in styling.

According to Sellstrom, "Duo-Tones" are offered in two types of temples. The new broad spatula style reportedly affords greater safety while the standard S-7 square lens shape allows interchangeability with present safety glasses. Both Rx prescription and plano lenses are offered.

For details, circle No. 112 on Reader Information Card.

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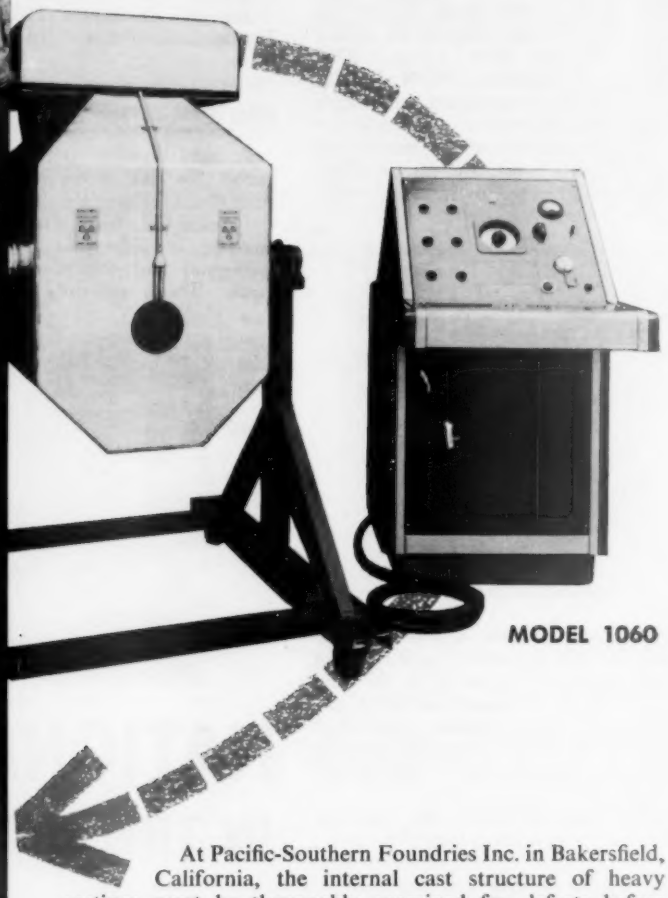
Nuclear Systems Economical, Portable Radiography Machines



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7	32	57	82	107	132
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9	34	59	84	109	134
10	35	60	85	110	135
11	36	61	86	111	136
12	37	62	87	112	137
13	38	63	88	113	138
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15	40	65	90	115	140
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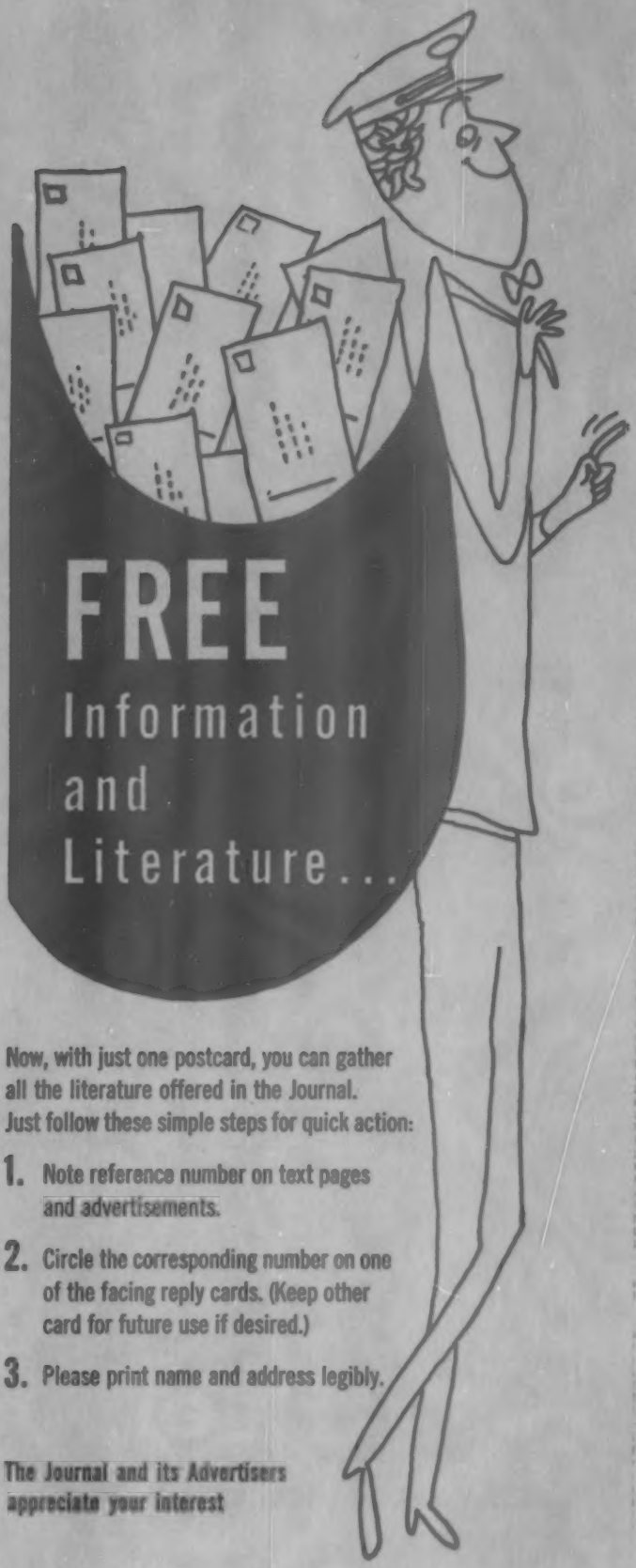

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SUPPLEMENT TO THE WELDING JOURNAL, AUGUST 1959

Metallurgy of Bonding in Brazed Joints

Part II—Migration of the Filler Metal into the Base Metal

Relationships between the metallurgical mechanisms involved and the mechanical properties of the brazed joints are investigated by the authors

BY NIKOLJAS BREDZS AND HARRY SCHWARTZBART

ABSTRACT. At practical brazing temperatures, the diffusion of the molten filler metal into the crystal lattice of the base metal is an extremely slow process and accounts for very little transfer of filler metal through the filler metal-base metal interface, even during a brazing cycle of several hours.

The principal mechanism of transfer of filler metal through the filler metal-base metal interface is shown to be by grain-boundary penetration, which is a rapid process. The mechanism of grain-boundary penetration and its interrelationship with other metallurgical phenomena involved are explored (1) theoretically, using diffusion concepts of Darken and phase-distribution concepts of Smith, and (2) experimentally, using metallography to study the operation of the various mechanisms.

Experiments utilizing a joining method termed "diffusion bonding" are described. The salient feature of this method is that the filler metal be completely diffused into the base metal, leaving no discrete joint. Use of this method for the joining of low-carbon steel and high-carbon steel (drill rod) yielded joints which were stronger than the base metal. Such joints in low-carbon steel were shown to be ductile in bending.

NIKOLJAS BREDZS and HARRY SCHWARTZBART are associated with the Metals Research Division, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.

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Introduction

The first paper[1] in the series of articles on "Metallurgy of Bonding in Brazed Joints" dealt with the solution of the base metal in the molten filler metal during the brazing process and with the subsequent mechanism of solidification of the filler metal saturated with the base metal.

The present paper, which is the second one of the series, deals with the problem of migration of the molten filler metal into the solid base metal. The main effort is concentrated on investigating the mechanism of the migration of copper filler metal into the steel base metal and defining the relationships between the metallurgical mechanisms involved and the mechanical properties of the brazed joints.

The reasons for the choice of steel base metal and copper filler metal for the fundamental investigation of the various types of migration processes in brazed joints were elaborated in Part I.[1] Because of the limited solubility of iron and copper in each other at brazing temperatures, the systematic study of the migration processes occurring in brazed joints is simpler than if there were complete mutual solubility.

It was also shown in Part I that in copper-brazed joints the molten filler metal becomes saturated with iron during the filling period of the capillary gap or very shortly afterwards. Therefore, one might postulate that since the saturation of the filler metal with base metal occurs rapidly and does not interfere with the subsequent migration of the filler metal into the base metal, the rate at which the latter occurs could be determined by measuring the decrease in thickness of the joint with time.

Migration Processes

For present purposes, the term "migration" is used as the general term which includes all the processes by which filler metal (in this case copper saturated with steel at the brazing temperature) proceeds into the base metal. This includes (1) diffusion, either lattice or grain boundary, without regard to whether the filler metal is molten or solid and (2) liquid metal grain-boundary penetration, which is considered to fall outside the definition of diffusion and is related rather to the mechanisms causing some instances of stress-corrosion cracking and hot shortness.

The precise experimental deter-

Table 1—Diffusion Parameters for Pure Copper-brazed Joints in Plain-carbon Steel (Calculated for Crystal-lattice Diffusion at 1100° C)

"Midway concentration" distance, a,		Time, t, required for obtaining the "midway concentration" at the distance, a	Decrease in thickness of the joint after times, t,	
in cm	in inches		in cm	in inches
0.1	0.04	44 years	0.02	0.008
0.01	0.004	4 months	0.002	0.0008
0.001	0.0004	29 hours	0.0002	0.00008
0.0001	0.00004	18 minutes	0.00002	0.000008
0.00001	0.000004	10 seconds	0.000002	0.0000008

mination of the rates of diffusion and grain-boundary penetration of the molten filler metal into the base metal was beyond the scope of this program. Crude attempts to accomplish this by measuring the decrease in joint thickness with time were unsuccessful because of two primary difficulties: (1) To obtain significant data it must be possible to measure the joint thickness before any migration (either lattice diffusion or grain-boundary penetration) of the filler metal into the base metal had occurred. This was impossible to do because during the first seconds of the brazing cycle some amounts of copper migrate into the steel. (2) Precipitation of copper-saturated iron dendrites on the steel-copper interface during cooling from brazing complicates and renders very difficult the measurements of joint thickness. Accordingly, published data were used to make a rough analysis of the amount of lattice diffusion expected during brazing.

Estimation of the Lattice Diffusion Coefficients and the Diffusion Rates for Copper in Dilute Solutions of Iron at Brazing Temperatures

A literature search revealed only one paper on the diffusion of copper into steel. This was a technical note by F. Karnik and R. Lindner.[2] From measurements of the β-radiation of radioactive copper on steel after a prolonged heating at temperature, they determined the diffusion coefficients of copper in dilute solutions of iron in the temperature range from 800 to 1200° C. According to their experimental data, these diffusion coefficients are equal to 3×10^{-10} cm²/sec at 1100° C and 1×10^{-9} at 1200° C. However, Karnik and Lindner do not mention in their work whether in computing these diffusion coefficients they also took into consideration the effect of the penetration of the liquid copper into the grain boundaries of steel or not. Thus, it is not known whether the relatively fast diffusion rates observed in their experiments reflect the "bulk diffusion," i.e., whether they reflect the lattice diffusion as well as the grain-boundary penetration.

All of the diffusion coefficients of various elements in dilute solution of iron at 800 and 1100° C were presented by Birchenall[3] in a 1950 paper; unfortunately, as of that time, no coefficients of copper in iron were available. However, because he showed the definite relationship between atomic radius of the diffusing element and the diffusion coefficient, and because iron and copper have almost identical atomic radii, it may be assumed, for present purposes, that the diffusion coefficient of copper in iron at 1100° C is equal to the self-diffusion coefficient of iron at 1100° C, i.e., D_{Cu} equals about 1×10^{-11} cm²/sec. Using this value of D and the simplified theoretical concepts reviewed by L. S. Darken[4] (the details of this treatment are given elsewhere[5]) it can be shown that the time required to diffuse appreciable quantities of copper from the filler-metal layer into the base metal is much longer than that available during a brazing cycle. This is shown in Table 1, where the calculated relationships among midway concentration, time and decrease in joint thickness are presented. Since according to the Cu-Fe diagram, the maximum concentration for copper in iron at 1100° C is about 8.4% and since the initial concentration of copper in iron may be assumed to equal zero, the midway concentration of copper in iron at 1100° C should be equal to $8.4/2 = 4.2\%$ Cu.

Examination of these results shows quite evidently that the amounts of copper which diffuse into the crystal lattice of iron, even during a brazing cycle of several hours, are quite negligible. For instance, in order to achieve a decrease of the thickness of the copper joint equal to 0.00008 in., a brazing cycle of 29 hr at 1100° C would be required. A decrease of the joint thickness equal to 0.0008 in. would require a 4-month long brazing cycle.

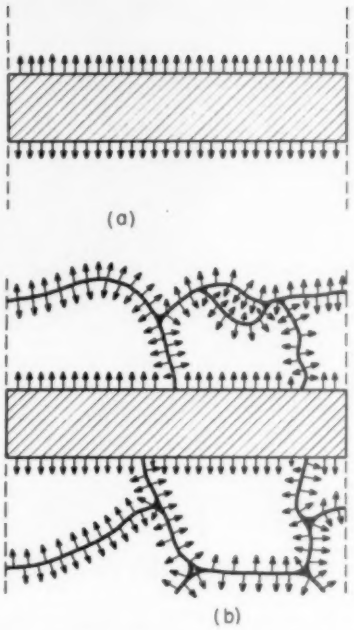

Fig. 1 —Schematic patterns diffusion of a liquid filler metal into a solid base metal (the arrows indicate the direction of the crystal lattice diffusion). (a) Without grain-boundary penetration. (b) With grain-boundary penetration

On the other hand, it is known that in induction brazing of steel bars with pure copper, in which case the copper remains in the molten state only for about 1 to 2 min, large amounts of copper penetrate into the grain boundaries of the steel, decreasing the joint thickness by at least 0.005 in. (estimated from micrographs). According to Table 1, in 1 to 2 min only negligible amounts of copper diffuse into the crystal lattice of the steel. These amounts are so small that the decrease of the joint thickness, due only to the crystal-lattice diffusion, cannot exceed 0.000001 in. Consequently, it can be concluded that by using induction heating for brazing of steel with pure copper, the amounts of copper which penetrate into the austenite grain boundaries are at least 5000 times larger than the amounts of copper which diffuse directly into the crystal lattice of the steel. Only if the heating cycle at 1100° C exceeded 4 months would the amounts of copper diffused into the crystal lattice of the steel approach the amounts of copper enclosed in the grain boundaries.

It is difficult to separate precisely the amounts of copper which penetrate into the grain boundaries of the steel and the amounts of copper which diffuse directly into the crys-

tal lattice of the steel even if the precise value of D were known. As soon as the liquid copper penetrates into the austenite grain boundaries, every grain of austenite close enough to the steel-copper interface will be surrounded by a thin film of liquid copper. Due to the penetration of the liquid copper into the austenite grain boundaries, the total area of the copper-steel interfaces will increase greatly. The total copper-steel contact area will be at least several times larger than in a joint without any grain-boundary penetration (Fig. 1). Diffusion of copper atoms from the given grain boundary into the crystal lattice of the austenite grain will start immediately upon the appearance of liquid copper in the grain boundary. Thus, the grain-boundary penetration, in turn, increases the crystal-lattice diffusion. A true estimate of the total amount of copper which diffuses into austenite crystal lattice in one unit of time must include the copper which diffuses through the original copper-steel interface plus the copper which diffuses from the austenite grain boundaries into the crystal lattice of the austenite. This is dependent upon the depth of grain-boundary penetration which is, in turn, dependent upon temperature, austenite grain size, heating rate, chemical composition of the steel, stress distribution in the steel, and large number of other factors. Therefore, an exact computation of the amounts of copper which will diffuse into the grain boundaries and the amounts of copper which will diffuse into the crystal lattice of the steel is impossible at this point.

Metallographic Studies of the Penetration of Liquid Copper into Austenite Grain Boundaries

In the course of the experimental work, a special etching technique was developed for distinguishing the steel saturated with copper from the steel which was not saturated.

In etching the polished cross sections of the copper-brazed mild steel bars with 2% Nital solution, it was observed that by using this etchant for a very short time (2 to 3 sec) it is possible to obtain microstructures with black-colored iron dendrites on the steel-copper interfaces. These dendrites which are precipitated from molten copper, and which consequently must be saturated with copper, are darker than the bulk of the steel which has not dissolved any copper (Fig. 2).

The same etching method applied to copper-brazed joints in high-carbon steel (drill rod) yields photomicrographs which show clearly the grain-boundary penetration and the lattice diffusion of the copper in high-carbon steel (Figs. 3 and 4).

These microstructures show not only the undissolved copper in the grain boundaries, but also the black shaded areas on both sides of the grain boundaries, into which the copper apparently has diffused. In some grain boundaries the undissolved copper cannot be detected, even under the highest magnification. However, the black-shaded zones adjacent to these boundaries prove quite evidently that copper has penetrated also along these boundaries and has subsequently diffused into the steel.

Thus, as a result of this etching technique, these micrographs show a rather complete picture of the grain-boundary penetration. Every austenite grain is surrounded by wide, black-shaded boundaries, so that the entire net of the grain boundaries is clearly outlined. On these micrographs the path of the grain-boundary penetration can be traced down to the last, minute quantities of the diffused copper, even in the most remote regions, quite far away from the copper-steel interface (in some regions even as far as $^1/_4$ in. from the interface). Moreover, a more thorough examination of the black-shaded grain boundaries reveals that in some cases they are composed of two, or even three, parallel lines. No reasonable explanation of this phenomenon has been found yet.

Of special interest, however, are the triangles consisting of undissolved copper which appear at the corners of the austenite grains. According to Cottrell,[6] "small amounts of a second phase in an otherwise homogeneous, polycrystalline alloy have a tendency to form at the grain boundaries of the latter, since an economy in the total boundary area can be achieved in this way, part of the large-angle boundary between the grains becoming the incoherent boundary of the second phase." Figure 5 illustrates the type of structure which is often formed in such cases, where a piece of a second phase, β, is lodged in the junction be-

Fig. 2—Copper-brazed joint in SAE 1020 steel. Etchant: 2% nital. × 75. (Reduced by one-third upon reproduction.) The precipitated, black-colored iron dendrites which are saturated with copper can be readily recognized in the filler-metal layer as well as on the steel-filler metal interface. Filler metal: pure copper. Brazing temperature: 2300° F.

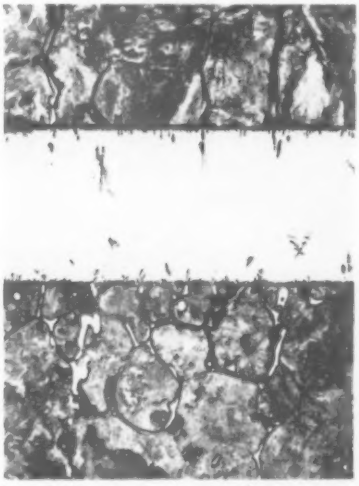

Fig. 3—Photomicrograph of a copper-brazed joint in high-carbon steel (drill rod), etched with 2% nital for a very short time. The penetration of the austenitic grain boundaries by liquid copper can be recognized very clearly in the lower portion of the micrograph. × 150. (Reduced by one-half upon reproduction)

Fig. 4—Enlarged photomicrograph of a portion of the steel-copper interface shown in Fig. 3. Etchant: 2% nital. × 500. (Reduced by one-half upon reproduction)

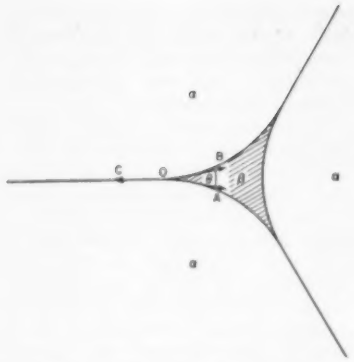

Fig. 5—A second phase (β) at the junction between three grains of a phase (α), according to A. H. Cottrell.

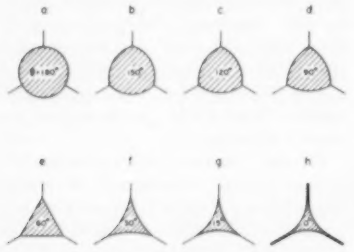

Fig. 6—Effect of dihedral angle on shape of second phase at line of intersection between three grains (C. S. Smith).

tween three grains of the main phase, α. After sufficiently long annealing at temperatures above the melting point of the phase, β, the shapes of such included phases become adjusted to minimize the surface energy of the system.

The Significance of the Dihedral Angles in the Mechanism of Grain-boundary Penetration

Using the idea of surface tension, Smith[7] deduces the *dihedral angle* or the *contact angle* (e.g., the angle θ in Fig. 5) from the balance of surface tension forces at the junction of the grain boundary (OC in Fig. 5) and the two-phase boundaries (OA and OB). If these surface tensions are denoted by $T_{\alpha\alpha}$ and $T_{\alpha\beta}$, respectively, the θ is given by the relation

$$T_{\alpha\alpha} = 2\, T_{\alpha\beta} \cos \frac{\theta}{2}$$

The equilibrium shapes for the included phase for various dihedral angles are shown in Fig. 8. As Cottrell[6] points out, the dihedral angle can have any value from 0 deg to 180 deg, depending on the value of $T_{\alpha\alpha}/2\,T_{\alpha\beta}$. If $2\,T_{\alpha\beta}$ is less than $T_{\alpha\alpha}$, the dihedral angle is zero and the second phase can spread as a continuous film between the grain

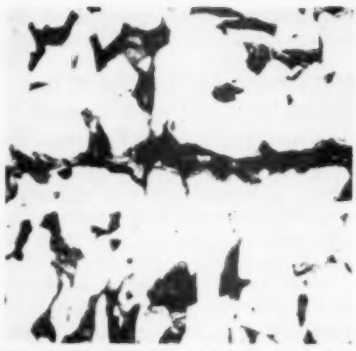

Fig. 7—Photomicrograph of a copper-brazed joint in low-carbon steel. The joint was subsequently heated for 30 min at 2200° F. The concentration of pearlite along the joint can be recognized very clearly. The regions above and below the joint are almost completely decarburized. Etchant: 2% nital. × 150. (Reduced by one-half upon reproduction)

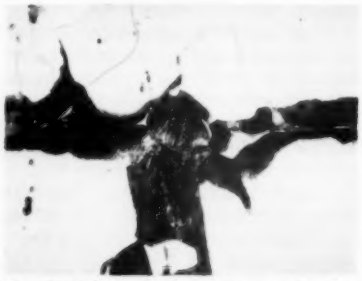

Fig. 8—Enlarged photomicrograph of a portion of the joint shown in Fig. 7. Etchant: 2% nital. × 500. (Reduced by one-half upon reproduction)

Fig. 9—Enlarged photomicrograph of a portion of the joint shown in Fig. 7. Etchant: 2% nital. × 1000. (Reduced by one-half upon reproduction)

boundaries of the main phase. If $2\,T_{\alpha\beta}$ is greater than $T_{\alpha\alpha}$, the dihedral angle is not zero and complete spreading is not possible.

Cottrell emphasizes that these conclusions are of great practical importance in the case where the second phase has a low melting point. "If the contact angle is zero, annealing above the melting point of the second phase will cause the alloy to disintegrate along the grain boundaries of the base metal, since the grain boundaries will be covered with continuous films of the liquid second phase."

It is interesting and pertinent to compare these theoretical considerations with the present observations. According to the theory, the dihedral angle would have to be zero to obtain the observed grain-boundary penetration. In other words, that means that

$$T_{Fe_\gamma} > 2\, T_{Fe_\gamma\text{-}Cu}$$

where $T_{Fe\gamma}$ is the average surface tension of the austenite grain boundaries and $T_{Fe\gamma-Cu}$ is the surface tension of the molten Cu-solid Fe_γ interface at the given penetration temperature.

However, examination of the micrographs, of which Figs. 5 and 6 are examples, reveals that the triangles of undissolved copper between three austenite grains show patterns resembling the ones shown in Figs. 6*d*, 6*e* and 6*f* which correspond to dihedral angles 90 deg, 60 deg, and 30 deg. One could reason from the dark bands surrounding the austenite grains that the dihedral angle was actually 0 deg, that diffusion has complicated the picture, and that one cannot consider the undissolved copper alone but must also consider the dissolved copper. Furthermore, conditions in the specimens of Figs. 3 and 4 certainly were not equilibrium. Therefore, the mechanism of the penetration of the molten copper into the austenite grain boundaries in this case is much more complicated than for the simple case cited by Smith.

Penetration of Liquid Copper into the Grain Boundaries of Low-carbon Steel

Figures 7 through 9 show a series of photomicrographs of a cross section of an extremely thin, low-carbon steel joint, induction butt brazed with pure copper under 10% H_2 + 90% N_2 atmosphere without any spacer wires. The brazed bars were subjected to additional heating in a furnace at 2200° F for 30 min, under argon atmosphere. Subsequently, the brazed bars were turned down to a standard 0.505 tensile specimen. In the tensile test, the specimen broke in the base metal at 58,800 psi. That means that the joint was stronger than the base metal. After fracture the joint was cross sectioned, polished and etched with 2% Nital solution.

Figures 7 through 9 show this cross section under various magnifications. It is evident from these

micrographs that after heat treatment for 30 min at 2200° F there is not much left of the original copper layer in the joint. The remnants of the original copper layer are present only in the corners of the austenite grains in the form of triangular prisms with concave sides. However, in some sections of the joint a few more or less coherent traces of the original copper layer can be discerned in the grain boundaries (Fig. 9, left side). The triangles of the undissolved copper—which represent the cross sections of the triangular prisms—show a pattern resembling the one shown in Fig. 6*h*, which corresponds to the dihedral angle, θ, equal to 0 deg, or at least very close to it. Consequently, in this case there are no discrepancies with the theoretical requirements for grain-boundary penetration developed by Smith and Cottrell. Furthermore, the photomicrographs shown in Figs. 7 through 9 reveal a peculiar structure in the base-metal layers adjacent to the joint. For the sake of a better surveillance we shall begin the examination of the microstructures of these layers on the photomicrograph taken under the lowest magnification (× 150), Fig. 7. The most characteristic feature of this micrograph is a comparatively wide, dark band enclosing the line of the original joint. The steel layers above and below this black-colored band are almost completely decarburized and show an almost 100% ferritic structure. Further from the joint, that is, above the white-colored upper band and below the white-colored lower band, the base metal has the typical microstructure of a furnace-cooled SAE 1020 steel. Under a higher magnification, in Figs. 8 and 9, the dark-colored band is seen to be pearlite with no traces of ferrite. The boundary between the dark-colored pearlite band and its branches and the white-colored ferrite layers is quite clear and sharply outlined (especially sharp in Fig. 9). The triangles of undissolved copper in the corners of the austenite grains and the remaining traces of the original copper film dissipated in the austenite grain boundaries are clearly visible within the pearlite band under higher magnifications (Figs. 8 and 9).

The joint shown in Figs. 7 through 9 was heated for 30 min at 2200° F. Accordingly, the molten copper had enough time during these 30 min to diffuse from the original copper-steel interface and from the copper-penetrated austenite grain boundaries quite deep into the crystal lattice of the austenite grains. On the other hand, it is evident from the photo-

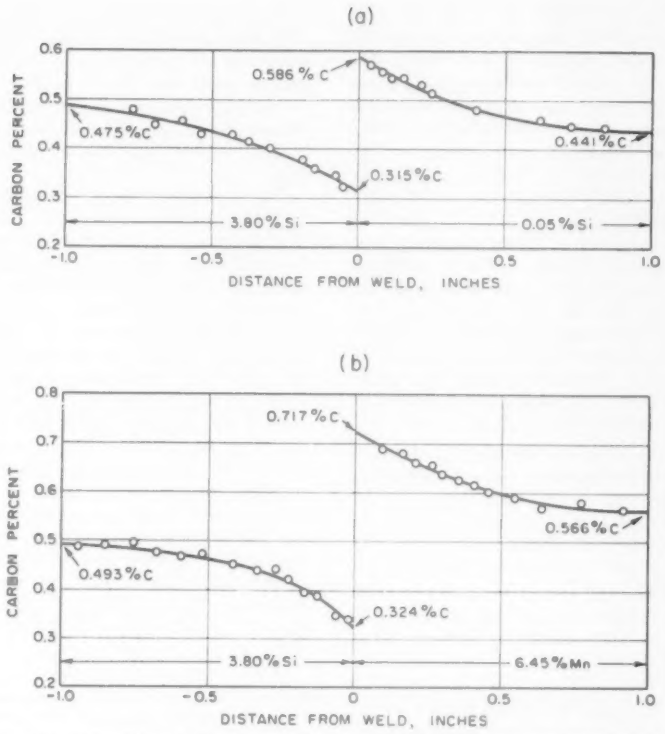

Fig. 10—Nonuniform distribution of carbon from initially uniform distribution (L. S. Darken).[8] (a) Carbon migrates from Fe-Si-C alloy to Fe-C alloy. Carbon distribution after 13 days at 1050° C (1920° F). (b) Carbon migrates from Fe-Si-C alloy to Fe-Mn-C alloy. Carbon distribution after 10 days at 1050° C (1920° F)

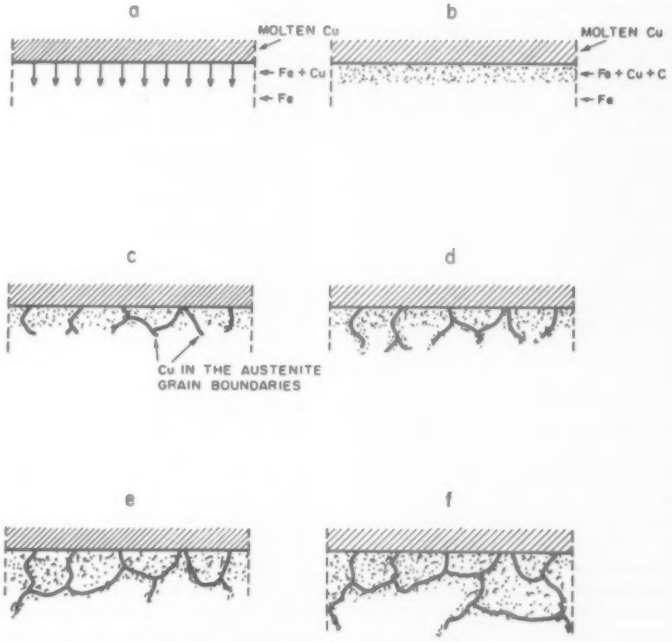

Fig. 11—Various phases of the diffusion of molten copper into the base metal in low-carbon steel joints

micrographs that in these 30 min practically all the carbon, which was originally present in the white, decarburized steel layers on both sides of the joint, had diffused into the copper-enriched austenite grains enclosing the joint. As a result of this diffusion during the 30 min of heating at 2200° F, every austenite grain boundary into which the copper has penetrated is enclosed between two layers of pearlite. This phenomenon is illustrated very effectively by Fig. 9. In this picture the pearlite band has four branches. Within each of these branches is enclosed a sharply outlined austenite grain boundary containing some traces of the original copper film.

Due to the concentration of pearlite on both sides of every austenite grain penetrated by copper, the width of the black-colored pearlite band is not continuous, and the shape of this band is somewhat irregular. In Fig. 7 the dark-colored pearlite band, running horizontally across the picture, has a large amount of smaller or larger dark-colored branches.

These pearlite branches point out the positions and indicate the direction of the austenite grain boundaries penetrated by copper.

Furthermore, the studies of the diffusion of carbon into the copper-enriched austenite grains support the belief that the dark-shaded austenite grain boundaries observed on the micrographs of the copper-brazed, high-carbon bars (in Figs. 3 and 4) are also caused by diffusion of carbon into the copper-rich austenite grain-boundary layers.

At first glance, the diffusion of carbon from the region of lower concentration into the region of higher concentration might appear to contradict the principles of classical diffusion theory. However, Darken[8] has shown how this can occur.

Darken has proven thermodynamically that, in multicomponent solutions, the diffusion flux of an atom of a certain kind depends directly not upon the concentration gradient but upon the free-energy gradient. He points out that diffusion may occur when the concentration gradient is zero if the free-energy gradient is not zero. In one of his experiments, Darken welded an iron-silicon-carbon bar to an iron-carbon bar of the same carbon content. He has shown that the initially uniform carbon content is disturbed to give a considerably nonuniform carbon distribution as illustrated in Fig. 10*a*. He also has shown that if an iron-silicon-carbon bar is welded to an iron-manganese-carbon bar of the same carbon content, then the carbon tends to diffuse from the silicon steel into the manganese steel, as shown in Fig. 10*b*. In simple language, this may be explained by saying that silicon rejects carbon, and manganese attracts carbon.

Furthermore, it is particularly noteworthy that Darken's carbon-distribution curves (Fig. 10) have been obtained after a diffusion treatment at 2050° F for 10 and 13 days, respectively. However, the steel joint which is shown in Figs. 7 through 9 was heated only for 30 min at 2200° F. That means that in Darken's experiments the heating period was about 500 to 600 times longer than in the present experiment. However, despite the much shorter heating time, the carbon-concentration gradient obtained at the ferrite-pearlite interface was at least 0.8% C, whereas in Darken's experiment the maximum carbon concentration gradient at the interface of the two steels (Fig. 10*b*) was only 0.717-0.324 = 0.393% C.

This comparison of the heating times and of the carbon concentration gradients obtained in the present and Darken's experiments shows quite effectively the striking ability of the dissolved copper atoms to "attract" carbon atoms. Therefore, from the theoretical point of view, it would be quite interesting to reproduce Darken's experiment on a system in which an iron-carbon-steel bar would be welded to an iron-carbon-copper bar of the same carbon content.

Relationship of Copper Penetration into Steel to Austenite-grain Growth

The melting temperature of copper (1981° F) is much higher than the pearlite-austenite transformation temperature of plain-carbon steels (1333° F). Therefore, at the time the copper melts and the molten copper starts to penetrate into the austenite grain boundaries, the austenite grains are in the process of a rapid growth. One question for consideration is whether the liquid copper film, which has penetrated into the grain boundaries all around the austenite grain, stops the further grain growth. To answer this question, work by Eckel and Paprocki[9] is pertinent. They developed a method for determining the austenite grain size in steel by diffusing copper and bronze intergranularly into steel at the austenizing temperature and showed that the molten copper inhibits further austenite grain growth as soon as it penetrates into the austenite grain boundaries.

The next pertinent question is whether the molten copper film in the austenite grain boundaries inhibits the diffusion of carbon from one austenite grain into another. Since carbon is insoluble in copper, it is reasonable to assume that this is the case.

The Combined Mechanism of the Diffusion and Grain-boundary Penetration of Liquid Copper in Plain-carbon Steels

The mechanism of the austenite grain-boundary penetration by liquid copper has been discussed in the light of the work by Smith and Cottrell. By use of Darken's simplified "midway concentration" formula, the rates of the lattice diffusion of copper in steel, as well as the depth of penetration and the amounts of copper which diffuse into the crystal lattice of the steel have been estimated. The diffusion of copper into copper-enriched areas has been explained by Darken's free-energy considerations. Finally, Eckel and Paprocki's investigations are helpful in elucidating the relationship between copper penetration and austenite grain size.

Utilizing all these concepts, one finds that the combined mechanism of the migration of molten copper into plain-carbon steel can be explained quite reasonably. This explanation is given in the two following sub-sections: the first considers the diffusion in eutectoid carbon steel, the second in low-carbon steel.

The Combined Mechanism of Migration of Copper in Eutectoid Carbon-Steel Joints. In eutectoid carbon steel the mechanism of migration of copper is much simpler than in low-carbon steels. As soon as the copper melts, it penetrates into the austenite grain boundaries almost immediately. By using induction heating the copper is in the molten state for only about 1 to 2 min. However, in these 1 to 2 min the molten copper penetrates quite deep into the austenite-grain-boundary net (Fig. 3). From the grain boundaries, the copper immediately starts to diffuse into the crystal lattice of the austenite grains. In turn, the carbon from the interior of the austenite grains will slowly start to move into the copper-enriched grain-boundary regions. The black-shaded austenite grain boundaries in Figs. 3 and 4 presumably are caused by such carbon diffusion. The austenite-grain growth in the copper-enclosed grains is inhibited, and no carbon diffusion into the austenite

grains enclosed by copper can take place.

The Combined Mechanism of Migration of Copper in Low-carbon Steel Joints. In low-carbon steel joints the mechanism of the migration of copper into the steel is much more complicated than in eutectoid steel due to the fact that the molten copper does not penetrate into the grain boundaries immediately after melting. No grain-boundary penetration has been observed in low-carbon steel joints brazed by induction heating. Only after a subsequent heating for 5 min at 2300° F some signs of grain-boundary penetration can be discerned at the copper-steel interface (Fig. 2). Apparently, the grain-boundary penetration in low-carbon steels starts gradually. In the first seconds after the molten copper fills the joint, the copper atoms start to diffuse from the copper-steel interface into the steel layers adjacent to the joint (Fig. 11*a*). Simultaneously the diffusion of carbon atoms into this copper-enriched steel layer adjacent to the joint begins (Fig. 11*b*).

Since the diffusion rates of carbon atoms in iron at practical brazing temperatures are about 40,000 times higher than the corresponding diffusion rates of copper, the concentration of carbon in the steel layers enriched by copper quickly attains eutectoid level. With the increase of the carbon concentration in the copper-enriched steel layers, the molten copper will gradually start to penetrate into the boundaries of the austenite grains (Fig. 11*c*) since this is now high-carbon steel (where, as has already been shown, grain-boundary penetration occurs quickly). Due to the gradual penetration of the molten copper into the austenite-grain boundaries, the total area of the copper-steel interfaces also will increase gradually. In turn, the increase of the total contact area will gradually increase the amounts of copper which diffuse into the crystal lattice of the austenite grains. The increase of the copper concentration in these grains then will increase the rate of carbon diffusion, in turn increasing the rate of growth of the thickness of the eutectoid carbon-steel layer enclosing the joint.

On the other hand, after a while the amounts of carbon which diffuse into the copper-enriched layer of steel will start to decrease due to the exhaustion of carbon atoms in the decarburized-steel layers enclosing the joint (Fig. 7). Furthermore, after a certain time the continuity of the growth of the layers of high carbon concentration on both sides of the joint will be gradually more and more distorted due to the formation of "branches" of high-carbon concentration along the austenite grain boundaries penetrated by molten copper (Fig. 11*d*). Figures 7 and 8 show quite effectively the formation of such "branches" of high-carbon concentration on both sides of the austenite-grain boundaries penetrated by liquid copper.

During the growth of the layer of high-carbon concentration, the growth of the austenite grains in the areas where the austenite-grain boundaries are not yet completely penetrated by liquid copper will continue. Due to the inhibition of the austenite-grain growth in the areas penetrated by liquid copper, the microstructures of the joint show a gradual increase of the austenite-grain size in the direction from the copper-steel interface into the steel area further from the joint (Figs. 11*e* and 11*f*).

Table 2—Tensile Properties of High-carbon Steel Joined[a] Under 10% H_2 + 90% N_2 Atmosphere

Specimen No.	Joining procedure	Joint thickness, in.	Ultimate tensile strength, psi	Remarks
1	Flowed-in filler. No spacer shims. Brazing cycle—51 min at 2050° F	0.00011	68,700	Steel and copper in the fracture surface
2	Flowed-in filler. No spacer shims. Brazing cycle—41 min at 2050° F	0.00006	69,700	Steel and copper in the fracture surface
3	Plated in $CuSO_4$. Brazing cycle—10 min at 2050° F	Not measurable	46,200	No copper visible in fracture surface
4	Plated in $CuSO_4$. Brazing cycle—10 min at 2050° F	Not measurable	106,500	No copper visible in fracture surface
5	Plated in $CuSO_4$. Brazing cycle—10 min at 2050° F	Not measurable	18,000	No copper visible in fracture surface
6	Plated in $CuSO_4$. Brazing cycle—10 min at 2050° F	Not measurable	80,400	No copper visible in fracture surface
7	Plated in $CuSO_4$. Brazing cycle—10 min at 2150° F	Not measurable	14,000	Traces of copper in the fracture surface
8	Plated in $CuSO_4$. Brazing cycle—4 min at 2200° F	Not measurable	113,000	No copper visible in fracture surface
9	Plated in $CuSO_4$. Brazing cycle—10 min at 2200° F	Not measurable	127,000	Broke in base metal
10	The bars were joined under the same conditions as in normal brazing except that no filler metal was used	...	90,800	Broke in base metal
11	The bars were joined under the same conditions as in normal brazing except that no filler metal was used	...	112,800	Broke in base metal

[a] Brazed, diffusion-bonded, or pressure-welded.

The Combined Mechanism of Migration of Copper in Alloy Steels

In the case of alloy steels with a low carbon content, the mechanism of the lattice diffusion of copper and the austenite-grain-boundary penetration will be much more complicated than in the case of low-carbon steels. For instance, Darken has shown that silicon "rejects" carbon and manganese "attracts" carbon in low-carbon steels. Therefore, variations in manganese and silicon contents will affect the rate of diffusion of carbon into the copper-enriched areas and thus the rate of grain-boundary penetration. The exact directions and potencies of the effects of manganese and silicon contents are impossible to predict because of the complexity of the operating factors such as microstructural distribution of alloying elements, phase relationships, and effects on transformation rates and temperatures.

These examples show that in order to understand the mechanism of the migration of copper in alloy steels the influence of each element of the alloy steels on the diffusion of copper should be investigated. No research has been done in this field, except for the two systems investigated by Darken.

Metallurgical Factors Affecting the Mechanical Properties of Thin, Copper-brazed Joints in Plain-carbon Steels

In prior work on this program,[10] it was observed that the tensile strength of extremely thin, copper-brazed joints in plain-carbon steels can considerably exceed that of the base metal. It was postulated that the exceptionally high strength is caused by: (1) complete diffusion of

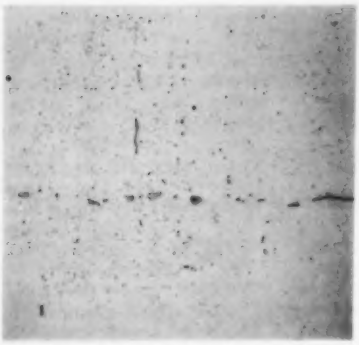

Fig. 12—Cross section of a diffusion-bonded joint in low-carbon steel. The brazed joint was heated for 30 min at 2000° F. Unetched. × 250. (Reduced by one-half upon reproduction)

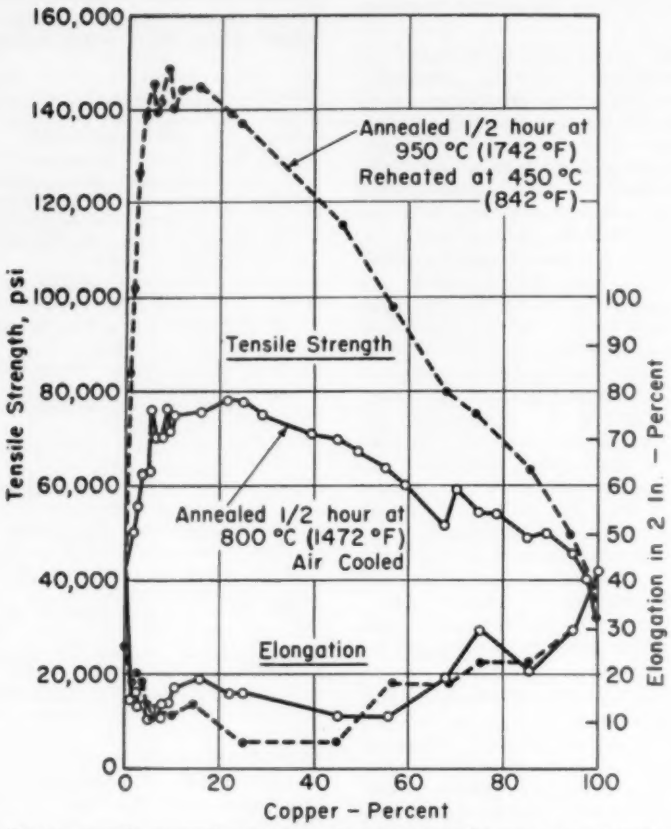

Fig. 13—Tensile properties of Cu-Fe alloys (C. S. Smith and E. W. Palmer). First series of curves (full lines) show tensile properties of specimens annealed $^1/_2$ hr at 800° C and air cooled; second series of curves (dotted lines) show tensile properties of specimens annealed $^1/_2$ hr at 950° C, and reheated at 450° C

the molten copper into the steel, resulting in "steel-to-steel" joints; (2) increase of the hardness of the steel layers adjacent to the joint, due to the diffusion of copper and carbon in these layers.

There was no doubt that this exceptionally high tensile strength must be very closely related with the mechanism of the penetration of the molten copper into the austenite-grain boundaries. Consequently, after this mechanism was sufficiently investigated, some experiments were performed to study the factors determining the tensile strength of the extremely thin copper-brazed joints in plain-carbon steels.

For these experiments, 3-in. long, $^3/_4$-in. diam low and high-carbon (drill rod) steel bars were butt induction brazed with copper in a 10% H_2 + 90% N_2 atmosphere according to procedures previously detailed.[10] No spacer wires were used for brazing of these bars, which were turned down to standard 0.505 tensile-test specimens after brazing.

As regards the use of filler metal, three general procedures were followed. Specimens 1 and 2 (Table 2) were made by flowing the copper filler metal into the capillary gap. To yield thinner joints the following procedure was followed for specimens 3 through 9: the end surfaces of these bars were polished to a high degree of precision, pickled in dilute H_2SO_4, and subsequently dipped for one minute into a concentrated solution of $CuSO_4$. The excess traces of sulfuric acid and copper sulfate were removed by rinsing the copper-plated surfaces in first 50% alcohol, then 96% alcohol. After removal from alcohol, the copper-plated surfaces were dried in hot air and, without any delay, clamped together and brazed in the induction-brazing apparatus. Specimens 10 and 11 were joined by processing under the same conditions as in normal brazing except that no filler metal was used.

When the joint thickness of the specimens which were copper-plated in $CuSO_4$ solution was measured under the microscope, no copper remained in the brazed joints, or at least the traces of copper in the brazed joints were so small that they could not be discerned even under the highest magnification. The phenomenon of the disappearance of the copper from the brazed joints has been observed on all samples which were copper-plated by dipping into $CuSO_4$ solution, independent of the brazing temperature or brazing time. In other words, the copper completely disappeared from the joints brazed at 2050° F for 2 min as well as from the joints brazed at 2200° F for 10 min.

The results of these experiments are given in Table 2.

It is appropriate at this point to discuss the terminology applied to the three general bonding processes represented by the data of Table 2. This is especially pertinent in view of the current widespread interest and application of these bonding processes.

For purposes of the present discussion, the data of Table 2 represent the following three bonding processes:

1. Brazing—Specimens 1 and 2. A discrete, continuous filler-metal layer remains in the joint after the joining cycle.

2. Diffusion bonding—Specimens 3 through 9. The filler metal in the capillary gap has, during or after the joining cycle, migrated into the base metal, leaving no discrete, continuous, filler-metal layer. Some small, isolated islands of filler metal may remain in what was the joint gap. This is illustrated in Fig. 12.

3. Pressure welding—Specimens 10 and 11. No filler metal is used at all. The joint is made only by temperature and pressure; and, depending upon the metal involved, one may or may not get grain growth across the interface.

Specimens 1 and 2, in which the filler metal was flowed-in and which exhibited measurable joint thicknesses even after being held at brazing temperature for 51 and 41 min, respectively, exhibited strengths around 69,000 psi and copper was visible in the fracture surfaces. The thinner diffusion-bonded joints made by dipping into $CuSO_4$ and bonding at temperatures from 2050 to 2200° F exhibited highly variable strength, and generally copper was not visible in the fracture surface. Of these, specimen 9, bonded at 2200° F for 10 min, broke in the base metal. Specimens 10 and 11, which were subjected to the same cycle as specimen 9 except that no filler metal was used, broke in the base metal. The only pressure applied to these bars during bonding was that supplied by the longitudinal thermal expansion of the bars during heating, applied against an end spring.

Summarizing these limited data, one may conclude that for the light pressures used in these experiments, a joining cycle of 10 min at 2200° F was adequate to yield 100% efficient joints, regardless of whether no copper filler metal was used or whether the amount was sufficiently small to migrate completely into the base metal during bonding. For copper plates thin enough to leave no measurable discrete joint after bonding and for bonding cycles below 10 min at 2200° F, strength was highly variable and did not exceed base-metal strength. For joint thicknesses of 0.00006 in. and 0.00011 in., joint efficiency was less than 100%.

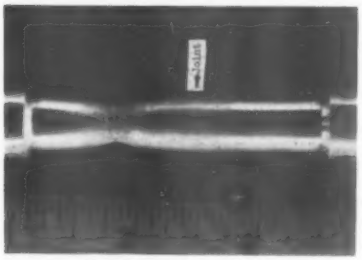

Fig. 14—Tension-tested copper-brazed low-carbon steel bar. Tensile strength: 69,100 psi. Joint thickness, 0.00032 in. After brazing, the specimen was heated to 1700° F for 1/2 hr, oil quenched and reheated for 4 hr at 850° F. Note that the bar deformed on both sides of the joint

Table 3—Tensile Properties of Low-carbon (1020) Steel Bars Brazed with Pure Copper (Austenitized at 1700–1760° F, Oil Quenched and Reheated at 840–850° F for 4 Hr)

Specimen No.	Joint thickness, in.	U.T.S., psi	Remarks
CLC 348	0.00294	71,200	Some small voids. Broke in filler metal
CLC 349	0.00257	75,000	Broke in base metal
Cu-1-LC	0.00023	70,800	Broke in filler metal
Cu-2-LC	0.00032	69,100	Broke in base metal
Cu-11-LC	0.00028	74,100	Broke in filler metal
Cu-12-LC	0.00039	70,800	Broke in filler metal

A word of discussion should be interjected in interpreting the results of the experiments utilizing copper films plated from $CuSO_4$. Possibly the extreme variability of the results is due to plating technique and the presence of deleterious plating films.

The low-carbon steel joint brazed with flowed-in copper (shown in the photomicrographs of Figs. 7 through 9) exhibited a strength of 58,800 psi and failed in the base metal. Since some small islands of copper did remain in the joint interface, it is seen that it is not necessary to diffuse all the copper into the base metal to get 100% joint efficiency in low-carbon steel, diffusion-bonded joints.

It has been shown[10] that the tensile strength of brazed joints increases with increasing base-metal strength. It has also been shown[1] that in solidified copper joints, the copper layer is sandwiched between two layers of iron dendrites, saturated with copper, which crystallized at the interface during cooling from brazing. Smith and Palmer[11] have shown that iron-copper alloys are precipitation hardenable (Fig. 13), so experiments were conducted to determine if joint strength could be increased by precipitation hardening the copper-saturated iron dendrites on both sides of the copper filler metal.

Bars of SAE 1020 steel, 3-in. long and 3/4-in. diam. were brazed in the normal fashion at 2050° F, with molybdenum wires of various diameters as spacers.

After brazing, the bars were turned down to standard 0.505-in. tensile-test specimens. The tensile specimens were austenitized for 1 hr at 1700° F, quenched in oil, and reheated for 4 hr at 840 to 850° F—exactly the same heat treatment as by Smith and Palmer (Fig. 13). After the heat treatment the bars were subjected to a tensile test.

The results are summarized in Table 3. Two of the bars, CLC-349 and Cu-2-LC, broke outside the joint. However, the rest of the

Fig. 16—The diffusion-bonded low-carbon steel bar after bending to 160 deg

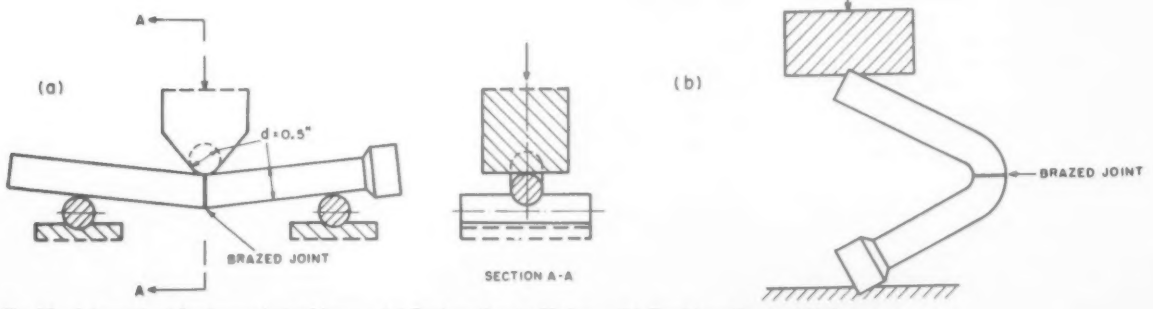

Fig. 15—A bend test for brazed steel bars. (a) Prebending to 35 deg. (b) Final bending to 160 deg

samples which fractured in the filler metal exhibited good strength.

Figure 14 is a photograph of tensile specimen Cu-2-LC which broke outside the joint. In this picture the unbroken copper joint is clearly visible in the center of the gage length. A careful examination of this picture reveals that the necking of the base-metal bars took place on both sides of the unfractured joint, indicating that the steel in the region of the joint was much stronger than the bulk of the base metal.

The significant conclusion to be drawn from the data presented in Table 3 is that it is not necessary to achieve complete disappearance of copper in the joint to obtain joints stronger than the base metal in low-carbon steel. These joints were relatively thick, as great as 0.003 in. Furthermore, although the heat treatment used in this series was identical to that used by Smith and Palmer,[11] a different treatment may be even more effective.

Ductility of Diffusion-bonded Joints

In order to investigate the ductility of diffusion-bonded steel joints, 3-in. long, $^3/_4$-in. diam, low-carbon steel bars were induction brazed with pure copper without any spacer wires in 10% H_2 + 90% N_2 atmosphere. Some of the brazed bars were subsequently heated for 10 min at 2200° F. All the bars were turned down to 0.5 in. diam and subjected to a bending test comprised of two operations (Fig. 15). A preliminary bending was accomplished by pressing a steel wedge on the joint until an angle of about 45 deg was attained. The next operation comprised pressing the free ends of the bars until an angle of 160 deg was formed.

The low-carbon steel bars which were brazed at 2050° F broke at 35 deg. However, all the bars which were heated after brazing for 10 min at 2200° F did not break even at 160 deg (Fig. 16). Considerable ductility, therefore, was exhibited.

Summary

This paper presents the findings of an investigation, both theoretical and experimental, into the mechanisms of the migration of copper filler metal into steel base metal, and the relationships between the metallurgical mechanisms involved and the mechanical properties of the brazed joints.

The results are summarized as follows:

At practical brazing temperatures, the diffusion of the molten filler metal into the crystal lattice of the base metal is an extremely slow process and accounts for very little transfer of filler metal through the filler metal-base metal interface even during a brazing cycle of several hours.

The principal mechanism of migration of filler metal through filler metal-base metal interface is shown to be by grain-boundary penetration, which is a rapid process. This is demonstrated (1) by theoretical means utilizing diffusion concepts reviewed by Darken, as well as his work on the effects of alloy content on carbon diffusion, and utilizing Smith's phase distribution concepts; and (2) by experimental means utilizing metallography to study the operation of the various metallurgical mechanisms involved. Due to the grain-boundary penetration of the austenite, the total interface area between the molten filler metal and the solid base metal is considerably increased which, in turn, increases the amounts of filler metal which diffuse into the crystal lattice of the base metal. Consequently, the composition, microstructure and hardness of the steel layers adjacent to the joint are appreciably altered. It is further shown that carbon diffuses toward regions of high-copper content in the base metal, which occur at the filler metal-base metal interface and in envelopes surrounding austenite grains. The operation of these fundamental mechanisms is a function of the carbon and alloy content of the base metal, and detailed examinations of low-carbon steel and drill rod show the effect of carbon content on these mechanisms.

Experiments utilizing a joining method termed "diffusion bonding" are reported. The salient feature of this method is that the filler metal be completely diffused into the base metal, leaving no discrete joint. Use of this method for the joining of low-carbon steel and drill rod yielded joints which were stronger than the base metal. Such joints in low-carbon steel were shown to be ductile in bending.

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Effect of Specimen Geometry on Charpy Low-Blow Transition Temperature

Investigation demonstrates that low-blow transition temperature, as determined by an easily executed variation of the standard technique for testing Charpy specimens is independent of notch and specimen geometry

BY GEORGE M. ORNER

ABSTRACT. It is demonstrated using a pearlitic and a martensitic steel that the Charpy low-blow transition temperature, as determined by an easily executed variation of the standard technique for testing Charpy specimens, is independent of notch and specimen geometry. The Charpy low-blow transition temperature is considered to represent the maximum temperature at which an initiating crack can propagate in a brittle (catastrophic) manner in a thick plate where the energy absorbed by the shear lips is negligible compared with the elastic energy available for crack propagation. The effect of striking the crack-initiating low blows at room temperature instead of at the temperatures selected for crack propagation was investigated. The results indicate that this modification of the testing technique has no measurable effect on the temperature at which the low-blow transition occurs.

Data are appended from low-blow transition temperature determinations on standard keyhole and V-notch Charpy specimens in T1 steel. The low-blow transition temperature is demonstrated to be considerably higher than the temperature corresponding to either the 10 ft-lb energy level on the conventional V-notch energy-temperature curve, or the mid-point of the scatter band on the conventional keyhole-notch energy-temperature curve.

Introduction

A recent investigation at Watertown Arsenal Laboratories, the fifth of a series with the over-all objective of evaluating and extending the usefulness of the Charpy impact test, demonstrated that in the single steel investigated (a pearlitic 3.3% nickel steel) the Charpy low-blow transition temperature was essentially independent of notch and specimen geometry.[1] The Charpy low-blow transition temperature is considered to represent the maximum temperature at which an initiating crack can propagate in a brittle (catastrophic) manner in a thick plate where the energy absorbed by the shear lips is negligible compared with the elastic energy available for crack propagation.

Supporting evidence that the Charpy low-blow transition temperature is a material property, independent of variables introduced by the test technique, was presented in a subsequent report in which the results from conventional (single-blow) Charpy impact tests indicated a quantitative correlation between the onset of self-propagating fracture (i.e., the highest temperature at which the crack became self propagating) and the low-blow transition temperature.[2] A discontinuity was shown to occur in the low-energy range of the *deformation-energy* plots, and the temperature corresponding to the energy level at this discontinuity was shown to correlate with the low-blow transition temperature when adiabatic temperature-rise effects were taken into consideration.

It was the objective of the investigation herein reported to determine: (1) whether low-blow transition temperatures would be independent of notch and specimen geometry in a variety of steels and (2) whether the low-blow technique could be simplified even further by striking the crack-initiating blow at a single convenient temperature instead of at the various temperatures used for the crack-propagating blow.

Table 1—Chemical Composition, %

Steel Type	C	Mn	Si	S	P	Ni	Cr	Mo	V	Cu
Class 90	0.17	0.33	0.23	0.030	0.04	2.13	0.97	0.22	0.03	0.057
Class B	0.195	1.31	0.04	0.025	0.017	..	0.05	..	..	0.174
Nickel	0.14	0.50	0.23	0.040	0.017	3.30	..	..	..	...

Material

The materials used in this investigation (Table 1) were: (1) a Class-90 steel, purchased under Ordnance Specification MIL-S-13326(ORD) in the form of a 1-in.-thick plate in the quenched-and-tempered condition; (2) a Class-B steel, purchased under the U. S. Army Specification No. 57-114-1 in the form of a 1-in.-thick plate in the as-rolled condition; and (3) the pearlitic 3.3% nickel steel used in the previous investigation.[1] Data obtained from an additional quenched-and-tempered steel (T1) are appended.

Standard V-notch Charpy impact energy-temperature curves and microstructures for each steel are presented in Fig. 1.

Test Procedure

As in the preceding investigation,[1] three notch types were used, viz., the standard Charpy V and keyhole notches, and a half-depth V notch for half-depth specimens.

GEORGE M. ORNER is a mechanical engineer in the Metals Joining Branch of the Watertown Arsenal Laboratories, Watertown, Mass.

The opinions or assertions contained herein are the private ones of the author and are not necessarily to be construed as official or reflecting the views of the Department of the Army.

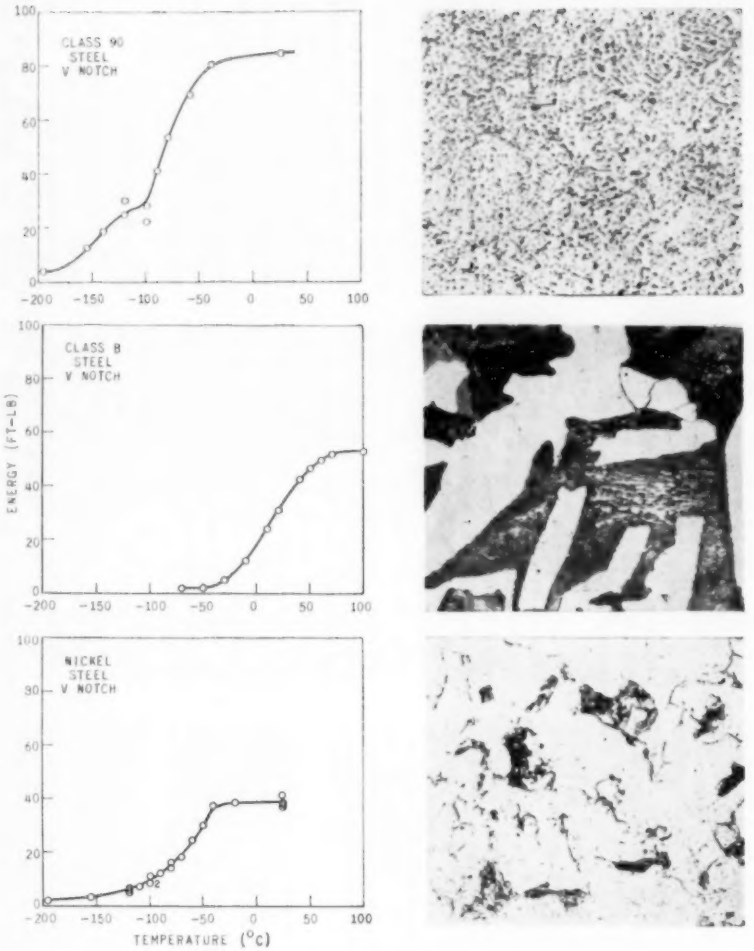


Fig. 1—Conventional Charpy impact energy-temperature transition curves and microstructures. (Nital etchant). ×1000. (Reduced by 1/3 upon reproduction)

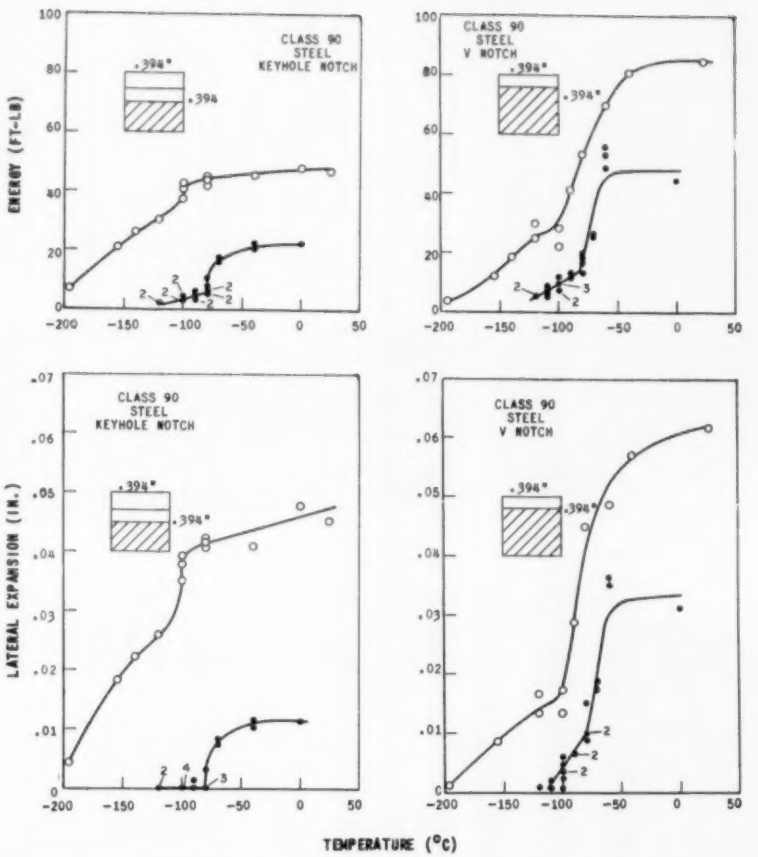


Fig. 2—Energy-temperature and expansion-temperature transition curves for standard keyhole and V-notch Charpy specimens in the Class-90 steel. The open circles (O) represent total energy or lateral expansion obtained from a single full-capacity blow; the filled-in circles (●) represent the energy or lateral expansion required to propagate the low-blow-initiated crack. Note that inflections denoting transition temperature occur at −80° C in all cases

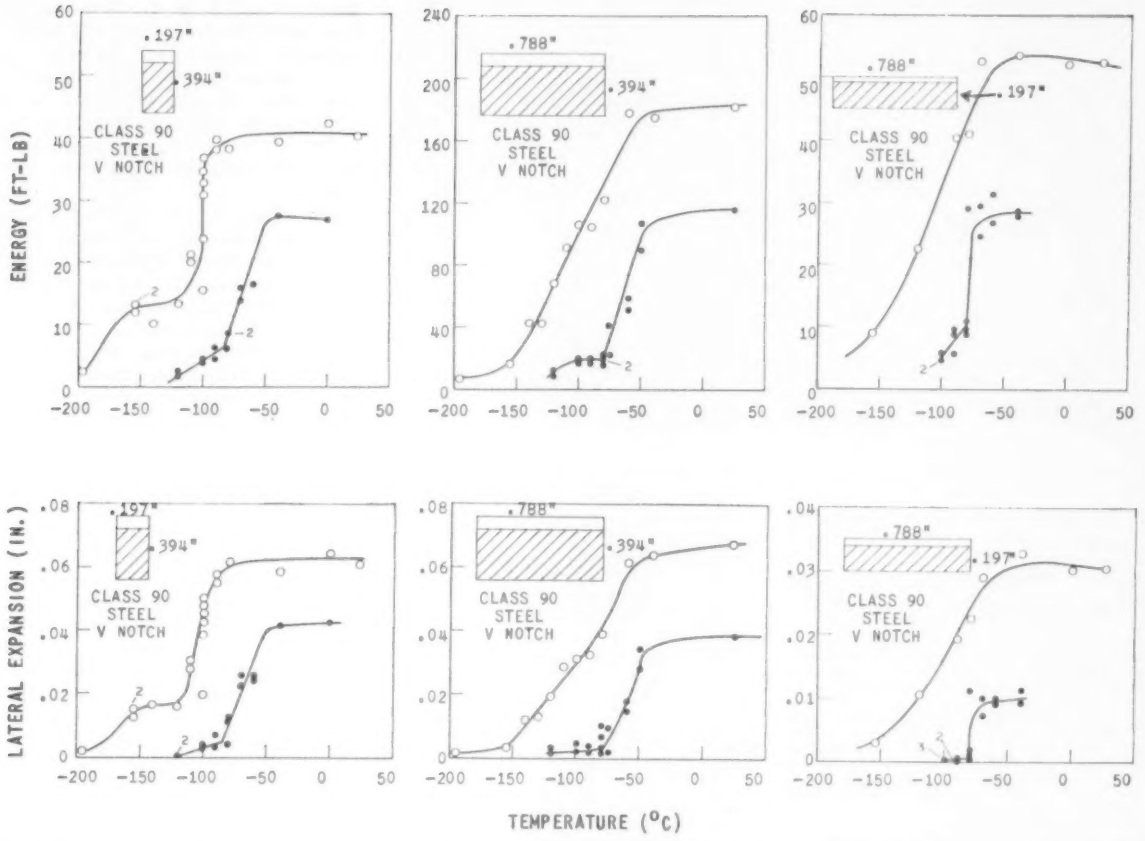


Fig. 3—Energy-temperature and expansion-temperature transition curves for half- and double-width V-notch Charpy specimens in the Class-90 steel. The open circles (O) represent total energy or lateral expansion as obtained from a single full-capacity blow; the filled in circles (●) represent the energy or lateral expansion required to propagate the low-blow-initiated crack. Note that the inflections denoting transition temperature occur at −80° C in all cases

The standard Charpy geometry was varied by halving the width (0.197 × 0.394 in.), doubling the width (0.788 × 0.394 in.) and doubling the width and halving the depth (0.788 × 0.197 in.).

Conventional (single, full-capacity blow) energy-temperature curves were obtained for each size and type of specimen for purposes of comparison. The remaining specimens were tested by the low-blow technique, which requires each specimen to be precracked and recooled before fracture. Precracking was accomplished in the Charpy machine by the use of a low-energy blow; just sufficient energy was used for each specimen type to cause small and consistent depths of crack as evidenced by ink staining. (India ink containing approximately 20% by volume of a wetting agent was used as a stain to determine the presence and extent of the initiating crack.)

In the first phase of this investigation, as in the earlier investigations, low blows were generally delivered at the temperatures selected for the crack-propagating blows. However, where specimens were tested at temperatures below the low-blow transition temperature and the initial blow resulted in complete fracture, the use of a higher temperature was necessary for crack initiation in order to obtain work-to-propagate data. In the second phase, in an attempt to simplify the low-blow technique and to facilitate obtaining data below the inflection point in the transition curve, the effect on the low-blow transition temperature of striking all crack-initiating low blows at room temperature, regardless of the temperatures selected for crack propagation, was investigated. This modification in techniques was applied to both steels of this investigation as well as to the steel of the earlier investigation using two specimen sizes, viz., the standard Charpy V-notch specimen and a half-depth double-width V-notch specimen.

Discussion of Results

The results from standard V- and keyhole-notch specimens, in the Class-90 steel, plotted on energy-temperature and expansion-temperature coordinates, are illustrated in Fig. 2. Note that although there is the usual displacement between the conventionally obtained Charpy keyhole- and V-notch curves, the inflections in the curves from the low-blow data fall at or close to −80° C for both specimen types. Similar data are illustrated in Fig. 3 for standard-depth specimens in double- and half-width sizes, and half-depth specimens in the double-width size. The inflections in the curves plotted from the low-blow data lie within a few degrees of −80° C for each specimen size.

In the case of the half-depth double-width specimens, some difficulty was experienced in determining the low-blow transition temperature. The minimum energy required to produce appreciable

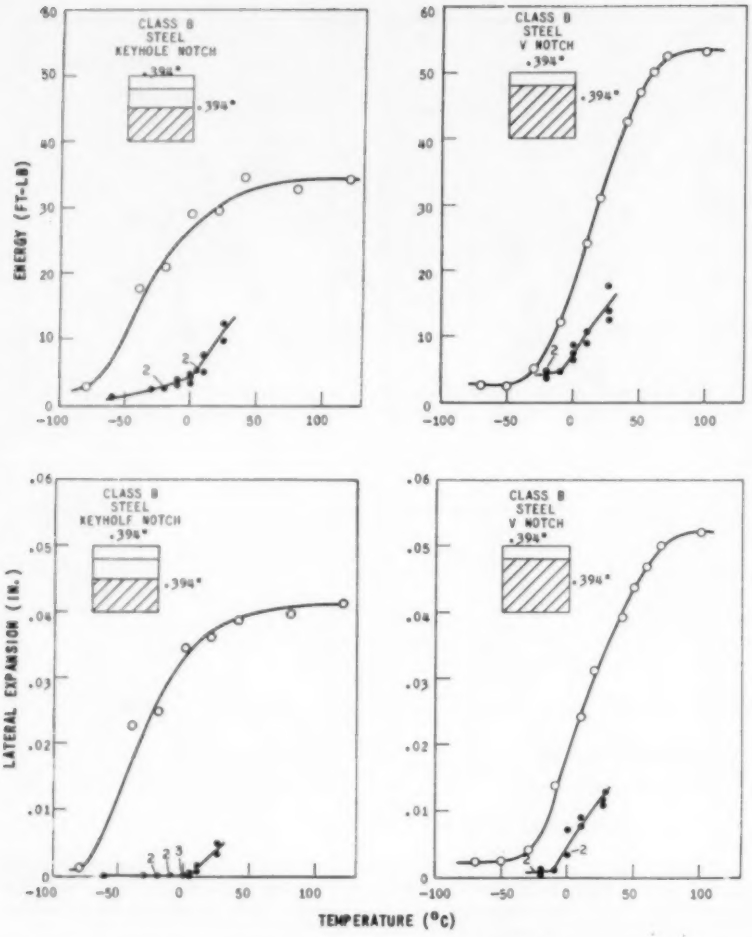


Fig. 4—Energy-temperature and expansion-temperature transition curves for standard keyhole and V-notch Charpy specimens in the Class-B steel. The open circles (O) represent total energy or lateral expansion obtained from a single full-capacity blow; the filled-in circles (●) represent the energy or lateral expansion require to propagate the low-blow-initiated crack. Note that the inflections denoting transition temperature occur close to —0° C in all cases

cracking (as detected by ink staining) was initially determined to be 21 ft-lb. When specimens were tested using this value, the low-blow transition temperature was indicated to be —100° C, instead of —80° C as observed from the tests in other specimen sizes. An examination of the fracture surfaces revealed that the 21 ft-lb low-energy blow was not quite sufficient to produce consistent ink staining. Apparently, too few specimens were used in the preliminary tests to accurately determine the minimum value of energy required to produce crack initiation.* Consequently, additional specimens were tested using a greater crack-initiating blow. Because only one set of unbroken specimens remained, and to insure that an adequate depth of crack would be produced, 30 ft-lb was used for the crack-initiating low blow. To avoid the possibility of fracture occurring as the result of the initial 30 ft-lb blow, all crack-initiating blows were delivered at room temperature. When propagation data from such tests were plotted, an inflection occurred at —80° C, which was in agreement with the other specimen sizes (see Fig. 3).

The Class-B steel, a coarse-grain† pearlitic material, was tested in a manner similar to that used for the Class-90 steel, and the results are presented graphically in Figs. 4 and 5. Although considerable scatter is evident in some of the data, low-blow transition temperatures of 0° C, plus or minus 10° C (maximum) are indicated for all notch and specimen geometries. Some difficulty was experienced in initiating cracks at and below the transition with the standard-size and the double-width standard-depth V notch specimens in this steel. In the latter specimen size, fracture occurred as a result of the low blow in all cases where crack initiation was attempted at or below the low-blow transition temperature. Therefore, for the double-width size the technique was modified by striking all crack-initiating blows at room temperature. An inflection in the curve plotted from these data occurred at —5° C. The small variations in the transition temperatures, as determined for the various specimen sizes, appear to have no significance and are thought to be due to inconsistencies in the steel which are frequently associated with coarse-grain materials.

Table 2 summarizes the low-blow transition temperatures determined for all the specimen and notch geometries tested in the two steels.

Crack Initiation at Room Temperature

Additional data were obtained to determine the effect of striking the initial low blows at room temperature rather than at the temperatures selected for the crack-prop-

* Crack-initiating energy values were intentionally chosen at the lowest possible values to lessen the chances of premature fracture occurring as a result of the low blow alone when delivered at a low temperature. In this case the low-blow energy proved to be too low.

† ASTM grain sizes 4 and 7 for pearlite and ferrite, respectively.

Table 2—Low-blow Transition Temperatures

Specimen size, in.		Notch type	Class-90 steel		Class-B steel	
Depth	Width		Transition temperature, °C	Low-blow energy, ft-lb	Transition temperature, °C	Low-blow energy, ft-lb
0.394	0.394	Keyhole	—80	28	0	18
0.394	0.394	Standard V	—80	35	—10	19
0.394	0.197	Standard V	—83	15	+5	12
0.394	0.788	Standard V	—80	70	—5[a]	46
0.197	0.788	1/2-Depth V	—80[a]	30	0	18

[a] Low blows struck at room temperature.

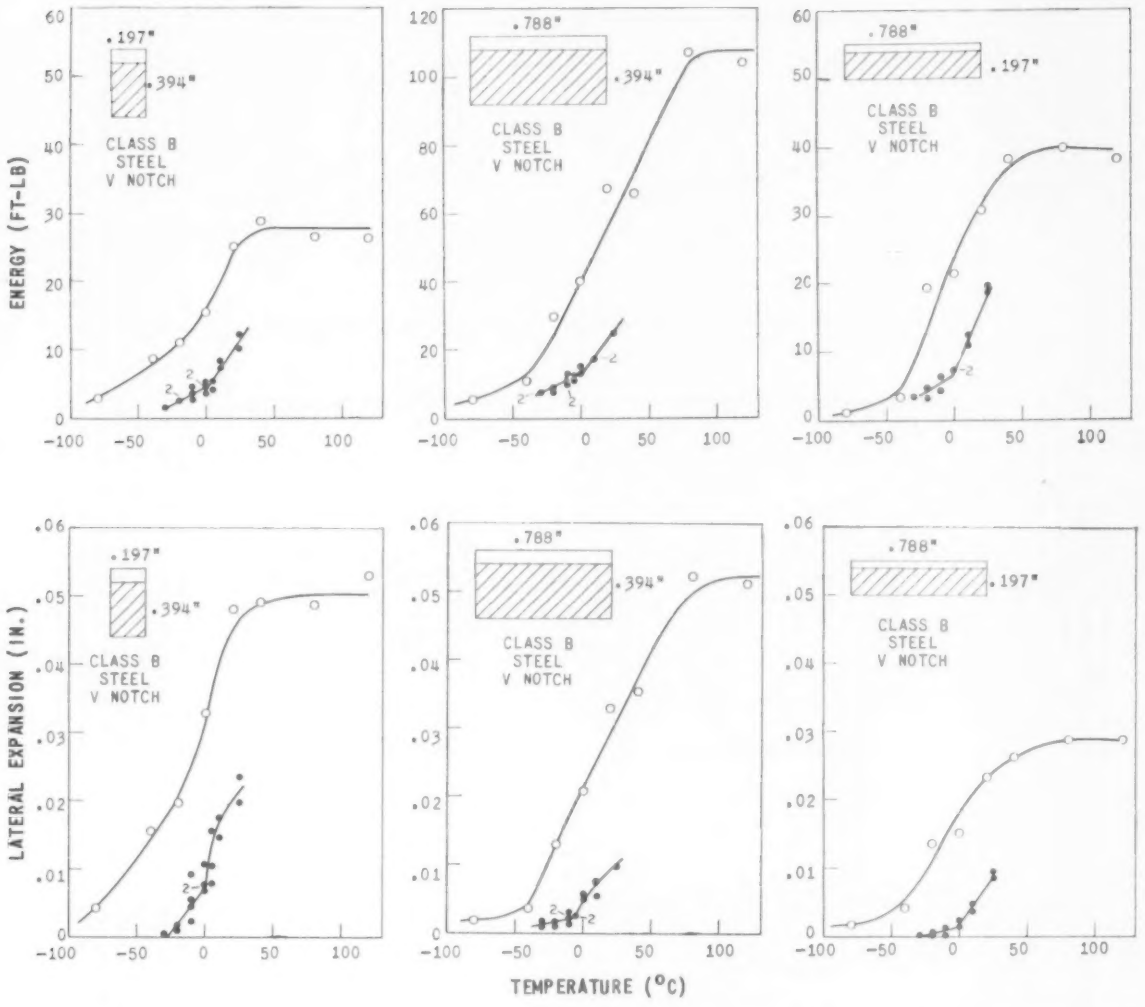


Fig. 5—Energy-temperature and expansion-temperature transition curves for various sizes of V-notch Charpy specimens in the Class- steel. The open circles (O) represent total energy or lateral-expansion as obtained from a single full-capacity blow; the filled-in circles (●) represent the energy or lateral expansion required to propagate the low-blow-initiated crack. Note that the inflections denoting transition temperature occur close to —0° C in all cases

agating blows. The results are presented in Figs. 6 through 11, where lateral expansion and energy values are plotted as functions of temperature. The left-hand illustrations in each figure depict crack-propagation data for crack initiation at room temperature, while on the right are data from tests where cracks were initiated and propagated at the same temperatures. The results are summarized in Table 3, where it is apparent that the low-blow transition temperature is essentially unaffected by the use of room temperature for the crack-initiating stage of fracture.

Note that in the case of the half-depth double-width specimens of Class-90 steel, the inflection occurred at −100° C instead of −80° C (a result of using too little energy for the initiating low blow). As was pointed out earlier, the 21 ft-lb low blow proved to be insufficient to produce appreciable ink-stained cracking. Furthermore, it was observed that large amounts of fibrous cracking (approximately 25% of specimen depth) preceded cleavage cracking when these specimens were fractured at −80° C, but that once cleavage cracking occurred it propagated through the remaining depth of specimen with little evidence of ductility. Thus, it appears that when the initial blow did not

Table 3—Summary of Results

Steel	Specimen size Depth, in.	Width, in.	Low blow at R. T. Energy, temperature, °C	Low blow at R. T. Expansion, temperature, °C	Low blow and fracturing blow at same temperature Energy, temperature, °C	Low blow and fracturing blow at same temperature Expansion, temperature, °C
Class 90	0.394	0.394	−80	−80	−80	−80
	0.197	0.788	−100	−100	−100	−100
Class B	0.394	0.394	−10	−10	−10	−10
	0.197	0.788	0	0	0	0
Nickel	0.394	0.394	−80	−80	−80	−80
	0.197	0.788	−75	−75	−80	−80

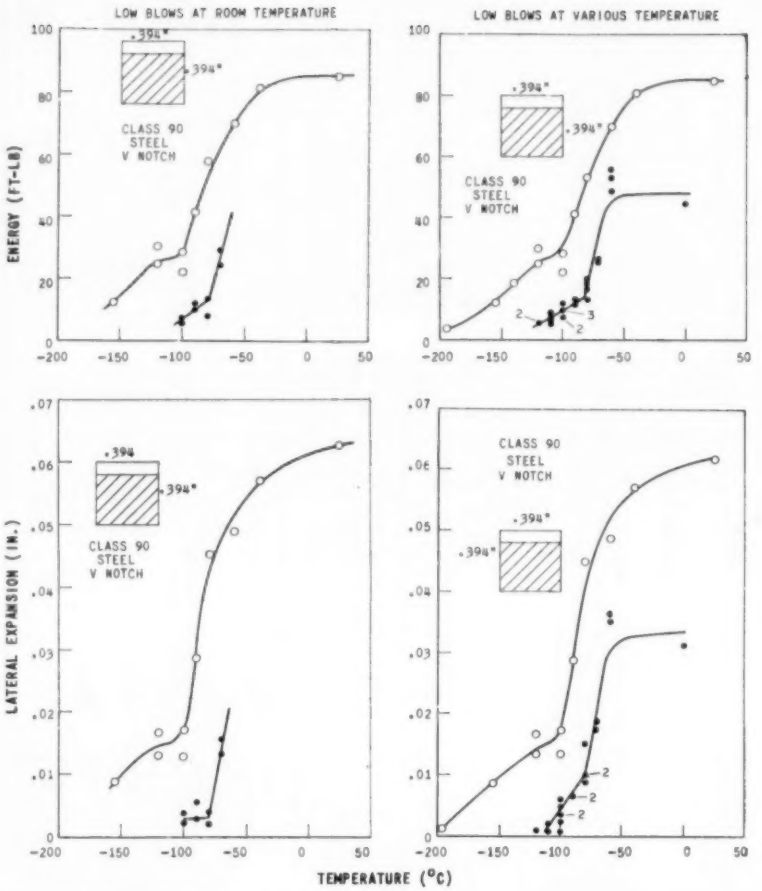


Fig. 6—Energy-temperature and expansion-temperature transition curves for standard V-notch Charpy specimens in the Class-90 steel. The open circles (O) represent total energy or lateral expansion obtained from a single full-capacity blow; the filled-in circles (●) represent the energy or lateral expansion required to propagate the low-blow-initiated crack. Note that there is essentially no change in the low-blow transition temperature when crack-initiating low blows are struck at room temperature instead of at the temperatures selected for crack propagation

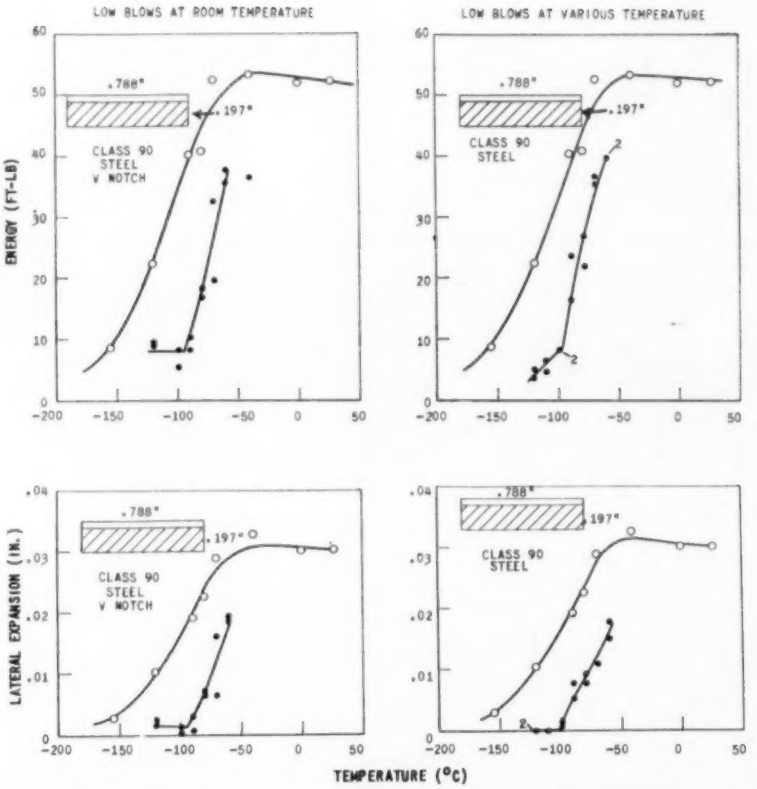


Fig. 7—Energy-temperature and expansion-temperature curves for double-width half-depth Charpy specimens in the Class-90 steel. The open circles (O) represent energy or lateral expansion from a single full-capacity blow; the filled-in circles (●) represent the energy or lateral-expansion required to propagate the low-blow-initiated crack. Note that there appears to be essentially no change in the crack-propagating data when crack-initiating low blows are struck at room temperature instead of at the temperatures selected for crack propagation

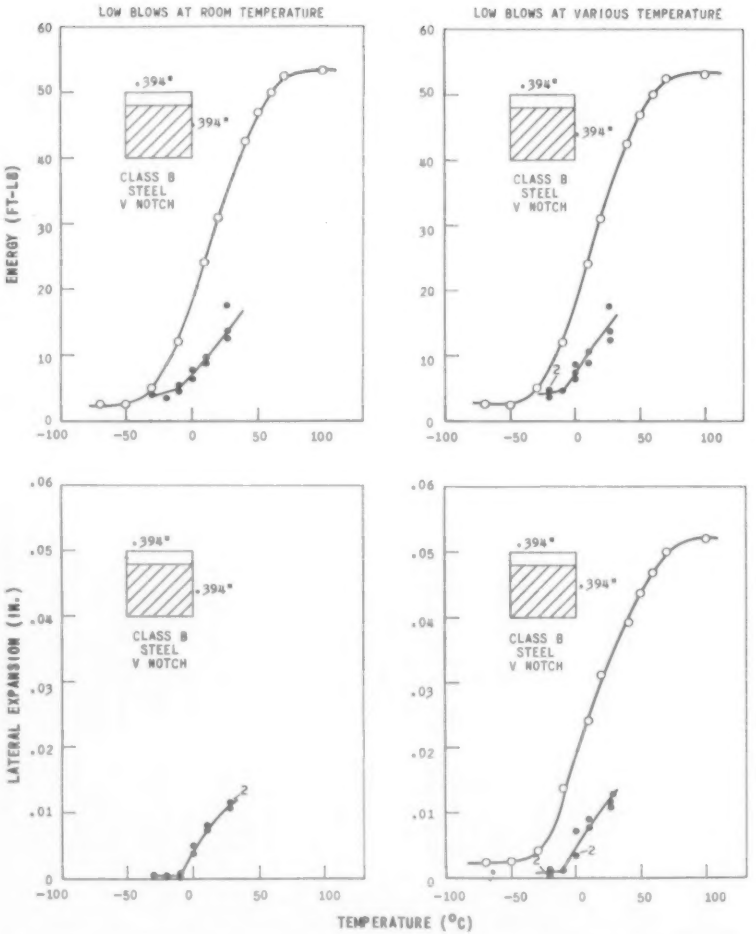


Fig. 8—Energy-temperature and expansion temperature transition curves for standard V-notch Charpy specimens in the Class-B steel. The open circles (O) represent total energy or lateral-expansion obtained from a single full-capacity blow; the filled-in circles (●) represent the energy or lateral expansion required to propagate the low-blow initiated crack. Note that there is essentially no change in the low-blow transition temperature when crack-initiating low blows are struck at room temperature instead of at the temperatures selected for crack propagation

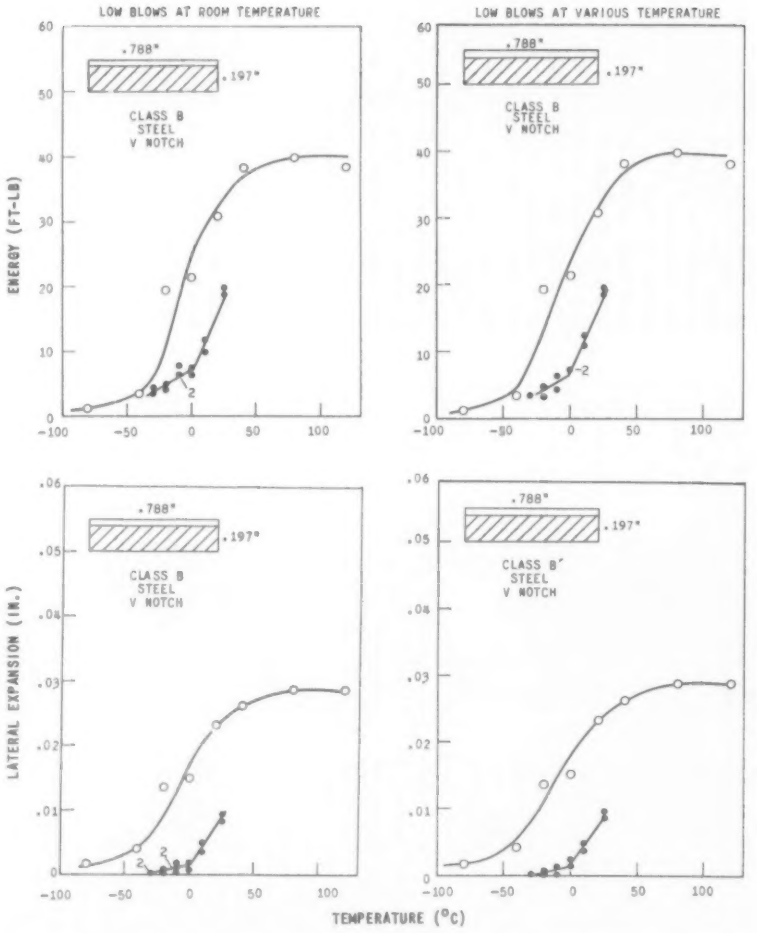


Fig. 9—Energy-temperature and expansion-temperature curves for double-width half-depth Charpy specimens in Class-B steel. The open circles (O) represent energy or lateral-expansion from a single full-capacity blow; the filled-in circles (●) represent the energy or lateral-expansion required to propagate the low-blow-initiated crack. Note that there is essentially no change in the low-blow transition temperature when crack-initiating low blows are struck at room temperature instead of at the temperatures selected for crack propagation

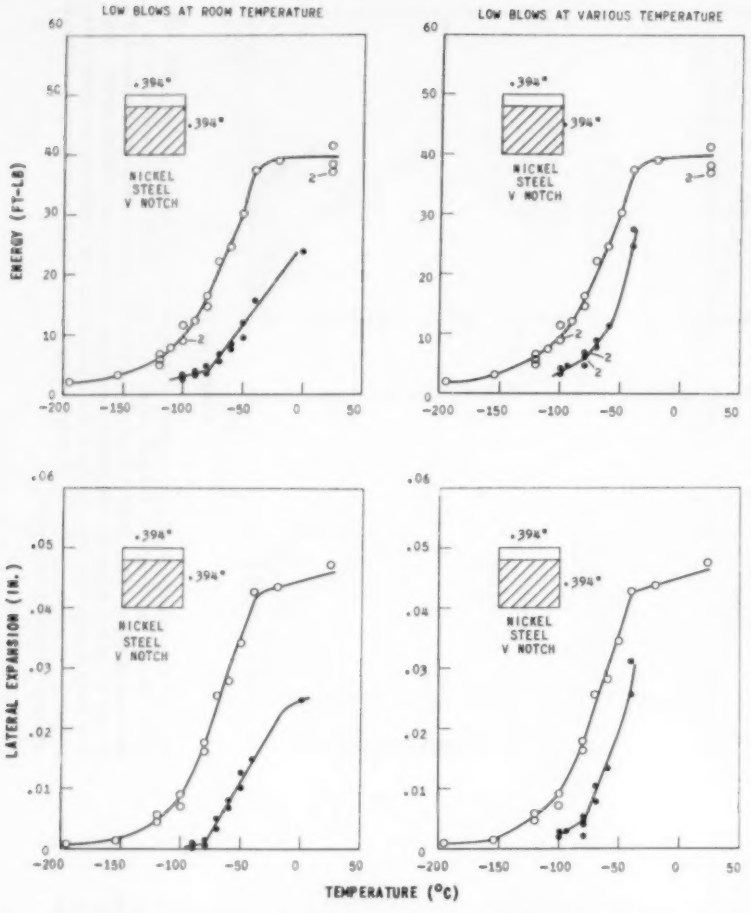


Fig. 10—Energy-temperature and expansion-temperature transition curves for standard V-notch Charpy specimens in the nickel steel. The open circles (○) represent energy or lateral expansion obtained from a single full-capacity blow; the filled-in circles (●) represent the energy or lateral expansion required to propagate the low-blow initiated crack. Note that there is essentially no change in the low-blow transition temperature when crack-initiating low blows are struck at room temperature instead of at the temperatures selected for crack propagation

produce sufficient plastic deformation to allow cleavage to initiate immediately on striking the crack-propagating blow, extensive plastic deformation work had to be done by the crack-propagating blow, which delayed initiation of cleavage cracking. When sufficient energy was used to produce unmistakable ink-stained cracking (30 ft-lb), the inflection in the crack-propagation data occurred at −80° C, the same temperature indicated by the other specimen sizes.

From Fig. 7 it will be noted that even though a fictitiously low transition occurred in the case of the half-depth double-width specimens struck 21 ft-lb low blows, the crack-propagation curves for the specimens initially impacted at room temperature are practically identical to the curves for the specimens where initial blows were delivered at the temperatures selected for crack propagation. The fact that the same anomalous transition temperature was indicated regardless of the temperature used for the initial blow is striking evidence that the temperature at which the low blow is delivered has little or no effect on crack propagation.

Conclusion

The low-blow technique is an easily executed variation in the standard technique for testing Charpy impact specimens which permits separation of the crack-initiation and crack-propagation stages of the fracture process. It has been demonstrated that the crack-initiating blow can be struck at room temperature, permitting greater economy and ease of operation. The low-blow transition temperature is independent of notch and specimen geometry within the limits of notch acuities and specimen sizes tested. From the results of these experiments and those of the preceding investigations, it is concluded that the low-blow transition temperature is a material property of considerable engineering significance in that it is believed to represent the maximum temperature at which an initiating crack can propagate in a brittle (catastrophic) manner in a heavy section where the energy absorbed by the shear lips is negligible compared with the elastic energy available for crack propagation.

APPENDIX

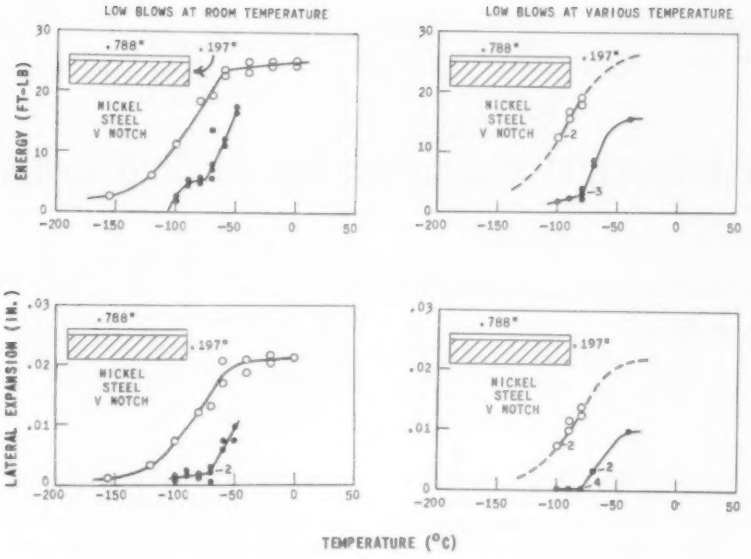
Low-blow transition temperature data for standard V- and keyhole-notch specimens were obtained from a particular heat of T1 steel. Conventional Charpy V and keyhole-notch data for this heat of T1 steel were obtained from a published report.[3] The chemical analysis in percent, of this material was as follows:

C	0.15
Mn	0.92
P	0.014
S	0.02
Si	0.26
Ni	0.88
Cr	0.50
Mo	0.46
V	0.06
Cu	0.32
B	0.0031

Owing to the limited quantities of material available for test from this particular heat of steel, few specimens were available for testing. Test procedures were similar to those described in the body of this report. The crack-initiation and crack-propagation stages of fracture were conducted at the same temperature, except in the case of V-notch specimens tested at and below the inflection temperature, where complete fracture occurred as a result of the low blow alone. In order to obtain crack-propagation data for the V-notch specimens at low temperatures, low-energy blows were struck at −60° C.

In spite of the scant data, it can be seen that well defined inflections (denoting low-blow transition temperature) occur between −75 and −80° C for both the keyhole- and V-notch specimens (Fig. 12).

Commonly used criteria for transition-temperature determinations are the 10 ft-lb energy level in conventional V-notch energy-tem-



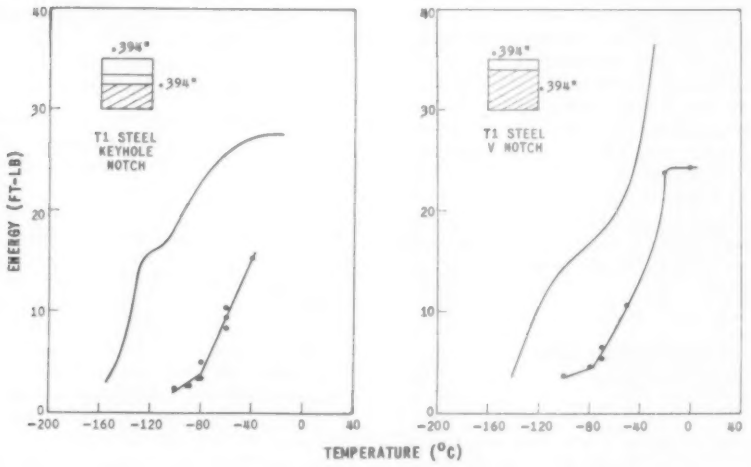


Fig. 12—Energy-temperature transition curves for standard keyhole- and V-notch Charpy specimens in T1 steel. The filled-in circles (●) represent the energy required to propagate the low-blow-initiated crack (conventional energy-temperature curves from Doty). Note that the inflection denoting low-blow transition temperature occurs at the same temperature for either specimen type

Fig. 11—Energy-temperature and expansion-temperature curves for double-width half-depth Charpy specimens in the nickel steel. The open circles (O) represent energy or lateral-expansion from a single full-capacity blow; the filled-in circles (●) represent the energy or lateral-expansion required to propagate the low-blow initiated crack. Note that there is essentially no change in the low-blow transition temperature when crack-initiating low blows are struck at room temperature instead of at the temperatures selected for crack propagation

perature data and the mid-point of the scatter band for conventional keyhole-notch energy-temperature data. Based on these criteria the transition temperatures indicated for this material are −120 and −136° C, respectively, i.e., temperatures considerably below the low-blow transition temperature. There is, however, little reason to expect a quantitative correlation between the low-blow transition and either of the two transitions cited above since (1) the use of 10 ft-lb as an energy level to denote transition temperature in an alloy steel is arbitrary and (2) with the conventionally tested keyhole-notch specimens, transition data are depressed by adiabatic temperature rise effects.[2]

Acknowledgment

The heat of T1 steel discussed in the Appendix was supplied through the courtesy of W. D'Orville Doty, United States Steel Corp., Pittsburgh, Pa.

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Isotope Techniques for Inspection and Evaluation of Ship Welds

Although other fast and inexpensive inspection methods are being investigated, radiography with isotopes has demonstrated its capabilities as a flaw-detection method

BY E. L. CRISCUOLO

ABSTRACT. Radiographic techniques utilizing Tm 170, Ir 192, Cs 137 and Co 60 were explored for the inspection of welds in $^1/_2$- to 2-in. steel plate. The information is presented in the form of technique and sensitivity curves. An analysis of these data has been performed and an empirical method has been developed to determine the optimum technique for a given thickness of material. For the inspection of welds in $^1/_2$- to 1-in. thickness range, iridium is the most promising isotope although other isotopes may be used satisfactorily. A review of data accumulated by the Ship Structure Committee on flaw evaluation is also presented. As a result of this investigation, a portable exposure container has been developed and is undergoing evaluation.

Introduction

The failure of ships at sea has caused great loss in lives and money. The Ship Structure Committee was established to study these failures in an effort to establish the cause and to work out possible solutions to the problem. A study has led to the belief that many of these failures were caused by faults located in the welds. To substantiate this theory, work has been conducted on the introduction of brittle fracture from weld faults.[1]

Studies have also been conducted in flaw detection and evaluation. The flaw detection program deals with the study of methods of nondestructive inspection of welds whereas the flaw evaluation deals with the interpretation of weld discontinuities as they affect a structure. In the flaw-detection program several projects were established. Kreiger, Wenk and McMaster at Battelle Memorial Institute[2] reported on the status of nondestructive-test methods for the inspection of welded joints. Following this work two projects were initiated—one at the Naval Ordnance Test Station, China Lake, Calif. on the development of a filmless inspection technique with isotopes,[3] and another at the Naval Ordnance Laboratory, White Oak, on the investigation of radioactive isotopes for the inspection of welds.[4]

Flaw evaluation programs were established at Swarthmore College and at Battelle Institute. In these programs the objective was to determine the effect of flaws in welds on the physical properties of the plate.

Flaw Detection with Radioisotopes

The use of radioactive material for industrial inspection is not new. As early as 1930 the use of radium gamma rays in radiography had been reported.[5] High cost and scarcity prohibited widespread use of this natural radioactive material. The availability of artificially produced radioactive material since 1946–47 has revived the interest in radiography with gamma rays. These radioactive isotopes have the advantages of low cost, availability and selection of energy.

The present work explores the use of radioactive isotopes for inspection of ship welds. The available radioactive sources, film, screens and techniques are being tried to determine an optimum radiographic technique for the inspection of hull welds of $^1/_2$- to 1-in. plate. Although the thicknesses mentioned are of primary interest, data are also being compiled to cover a range of $^1/_2$ to 2 in. of steel to anticipate any future demand. The bases for evaluation are: (1) inspection quality, (2) speed, (3) economy and (4) safety of operation.

Until further information regarding the size and shape of a defect that may be considered harmful is made available, the two percent sensitivity level is being used as a quality guide.

Radioactive Sources

Two basic types of radiation sources are available for industrial radiography, (1) the X-ray generator and (2) the radioisotope. The X-ray generator converts electrical energy into X-rays and the radioisotope produces gamma rays continuously as a result of atomic disintegrations. Each radiation source has specific advantages as well as disadvantages. In this presentation only the radioactive isotope will be discussed. Although a large number of radioisotopes have been explored for industrial radiography, only the most promising ones are considered in this investigation. These are thulium, iridium, cesium and cobalt.

Thulium 170. Thulium 170 is a pile-produced isotope of low energy, low output and low specific activity. Its low energy makes this isotope suitable for the inspection of thin sections. It has a half life of 127 days and its spectrum contains one predominant gamma ray line of 0.083 Mev. In addition to the gamma ray line, it has several high-energy Beta lines. These electrons produce bremsstrahlung radiation of high energy. The net result is a source with one low-energy and several high-energy lines. In an absorption curve the attenuation for the first few half value layers is characteristic of the 0.083 Mev gamma and at larger thicknesses the attenuation is characteristic of the

E. L. CRISCUOLO is associated with the U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Md.

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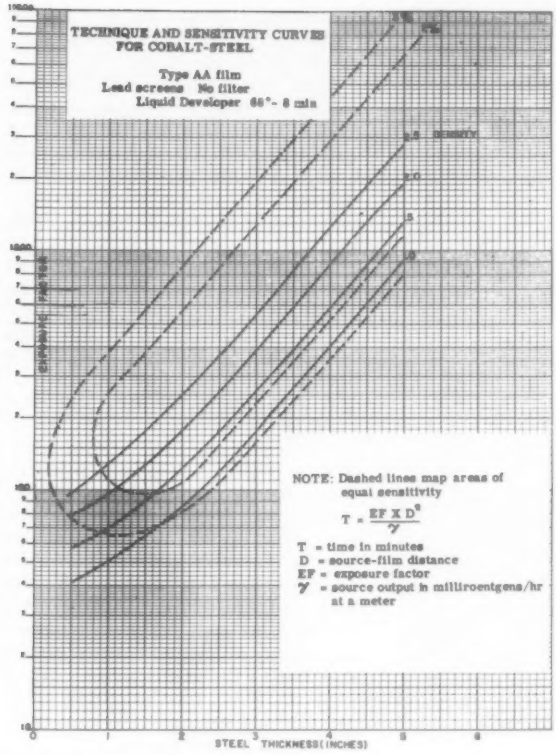
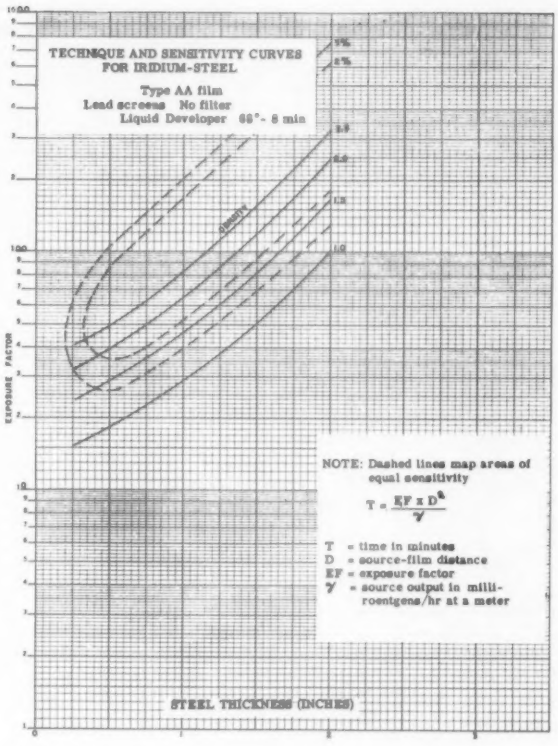

TECHNIQUE AND SENSITIVITY CURVES
FOR COBALT-STEEL
Type AA film
Lead screens No filter
Liquid Developer 68°- 8 min
NOTE: Dashed lines map areas of equal sensitivity
T = EF X D²/γ
T = time in minutes
D = source-film distance
EF = exposure factor
γ = source output in milliroentgens/hr at a meter
EXPOSURE FACTOR
STEEL THICKNESS (INCHES)

(Type AA is a medium-speed film)

Fig. 1—Technique and sensitivity curves for cobalt-steel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FOR IRIDIUM-STEEL
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D = source-film distance
EF = exposure factor
γ = source output in milli-roentgens/hr at a meter
EXPOSURE FACTOR
STEEL THICKNESS (INCHES)

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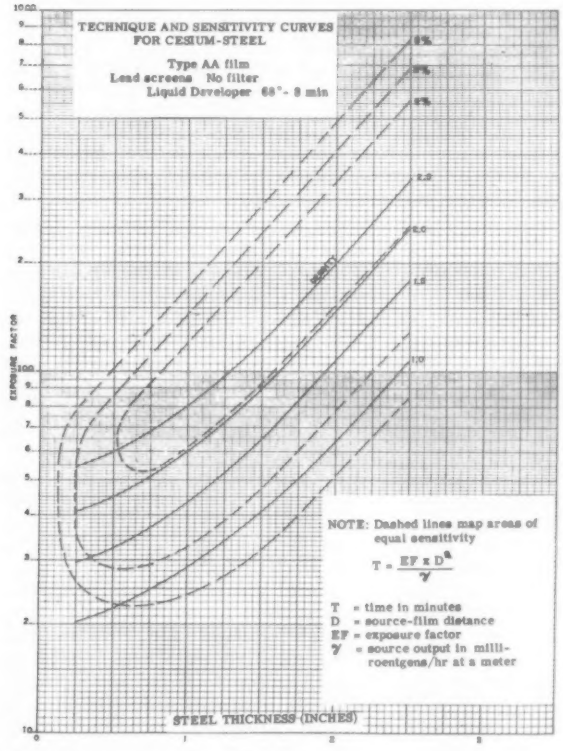
Fig. 3—Technique and sensitivity curves for iridium-steel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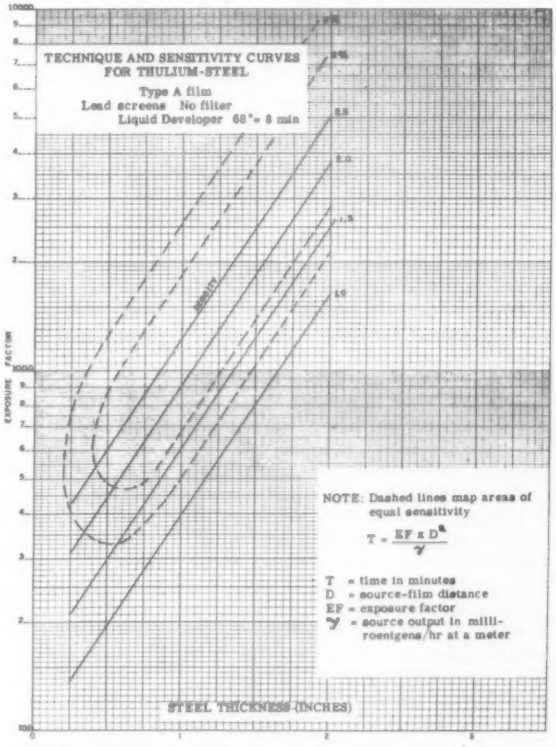
NOTE: Dashed lines map areas of equal sensitivity
T = EF x D²/γ
T = time in minutes
D = source-film distance
EF = exposure factor
γ = source output in milli-roentgens/hr at a meter
EXPOSURE FACTOR
STEEL THICKNESS (INCHES)

(Type AA is a medium-speed film)

Fig. 2—Technique and sensitivity curves for cesium-steel


TECHNIQUE AND SENSITIVITY CURVES
FOR THULIUM-STEEL
Type A film
Lead screens No filter
Liquid Developer 68°- 8 min
NOTE: Dashed lines map areas of equal sensitivity
T = EF x D²/γ
T = time in minutes
D = source-film distance
EF = exposure factor
γ = source output in milli-roentgens/hr at a meter
EXPOSURE FACTOR
STEEL THICKNESS (INCHES)

ype A is a medium-speed film)

Fig. 4—Technique and sensitivity curves for thulium-steel

Table 1—Comparison of Techniques for ¾-in. Steel Plate Density 2.0

Film designation	Screen	Filter	Exposure factor	Sensitivity, %
THULIUM 170				
M	Pb	None	850	2
M	Pb	0.030 Pb	2200	1
A	Pb	None	650	2
A	Pb	0.030 Pb	1150	1
AA	Pb	None		
AA	Pb			
F	Pb	0.030 Pb	250	2
F	Calcium tungstate	0.030 Pb	10	3
IRIDIUM 192				
M	Pb	None	500	2
M	Pb	0.030 Pb	650	1
A	Pb	None	166	2
A	Pb	0.030 Pb	116	1
AA	Pb	None	50	2
AA	Pb	0.125 Pb	55	1
F	Pb	0.030 Pb	65	2
F	Calcium tungstate	0.030 Pb	12	2
CESIUM 137				
M	Pb	None	300	2
M	Pb	0.125 Pb	620	2
A	Pb	None	100	3
A	Pb	0.125 Pb	180	2
AA	Pb	None	51	3
AA	Pb	0.125 Pb	100	2
F	Pb	0.125 Pb	80	3
F	Calcium tungstate	0.25 Pb	14	3
COBALT 60				
AA	Pb	None	86	3
A	Pb	None	155	3
F	Pb	0.25 Pb	185	4
F	Calcium tungstate	0.25 Pb	12	3

Film types: M = slow; A, AA = medium; F = fast.

bremsstrahlung radiation. In thicknesses over ½ in. of steel, the absorption characteristics of the high-energy radiation predominates. Since the bremsstrahlung radiation output is low, thulium is practically eliminated as a source for inspection in this application.

Iridium 192. Iridium 192 is a pile-produced isotope that has gamma lines extending from 0.200 Mev to 0.606 Mev with 0.315 Mev and 0.457 Mev lines most intense. A curie of iridium has an output of 0.55 roentgens per hour at one meter. It is available with specific activities as high as 50 curies per gram. Its short half life of 74 days is an inconvenience for industrial use and necessitates a system of periodic replacement of sources.

Cesium 137. Cesium 137 is a fission product that has a single gamma line at 0.66 Mev. Its half life is about thirty years, an advantage for industrial radiography. A curie of cesium has an output of 0.39 roentgens per hour at one meter. It is available with specific activities of 24 curies per gram of salt with a density of the pellets about 3.5 g per cu cm.

Cobalt 60. Cobalt 60 is a pile-produced isotope with a half life of 5.3 yr. It emits gamma radiation of 1.17 and 1.33 Mev. One curie of cobalt has a radiation output of 1.35 roentgens per hour at one meter. The isotope can be bought with specific activities as high as 50 curies per gram.

Technique and Sensitivity Data

A useful method for presentation of technique and sensitivity data on the various radioactive sources is by means of the technique and sensitivity loops. The sensitivity loop was originally described by Johns and Garrett[6] and the combination of the technique and sensitivity curves was devised by O'Connor and Hirschfield.[7]

The data taken on the sources investigated are in the form of the curves described above. Figures 1 to 4 are for medium-speed film. The straight lines are the technique curve for several film densities. The dashed loops are the sensitivity curves which define the area on the technique chart where a given sensitivity is attainable.

Data was accumulated for various speed films, sources and filters. About three sets of curves were obtained with the different conditions. A summary of this information for ¾-in. of steel absorber at a density of 2.0 is shown in Table 1.

All the curves indicate that the best sensitivity is obtained with a film density of 2.0 or 2.5. The radiographic sensitivity in many cases is improved by inserting a lead filter between the object and the film.

A comparison of the four isotopes with a medium-speed film at the two percent penetrameter sensitivity level is shown in Fig. 5. In the range of specific interest, ½ to 1½ in. of steel, iridium has the shortest exposure factor and therefore for ¾-in. plate is considered the best available source. It is felt that the disadvantage of a relatively short half life can be overcome by a planned replacement schedule.

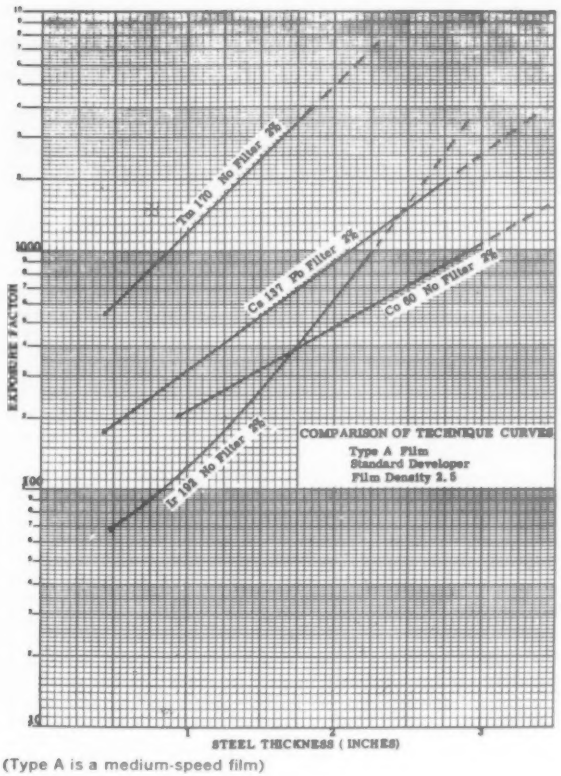
Handling System

In order to use a source efficiently and safely, a good handling system is necessary. Many manufacturers have developed excellent equipment for handling both small and large sources.

In the shipyards it is desirable to be able to make an exposure without interfering with other activities. According to present-day practice, the exposure areas are restricted, or the work is done during periods of inactivity.

In industrial radiography three safety conditions must be met. The first is proper storage when not in use. The source container must be designed that the level of radiation is reduced to 10 milliroentgens/hr at one meter from the source. The second safety condition is operator protection. Apparatus must be designed so that the maximum exposure received by the operator is negligible. The third safety condition is the protection of personnel working in the area, particularly on the far side of the weld under inspection.

Many methods have been developed and devised to handle radioactive material for radiography. The simplest of these methods, which is practical for low-strength sources, is the fish-pole system with a bare source. The source, which has a hook or string attached to it, is stored in a lead pot or container. The source is removed from the pot



(Type A is a medium-speed film)

Fig. 5—Comparison of technique curves

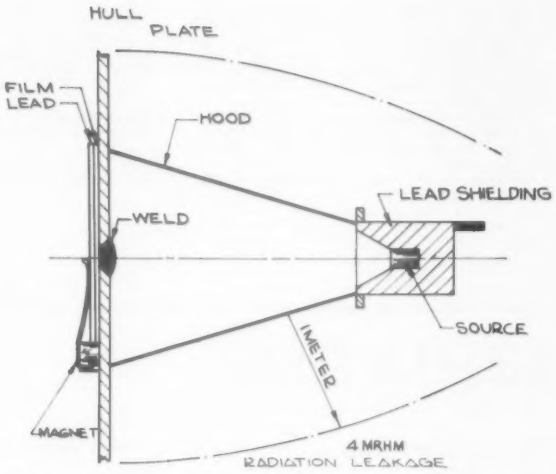


Fig. 6—General layout of exposure fixture and radiation-leakage pattern

with a long rod and placed into position for radiography. A variation of this method of handling isotopes has the source permanently mounted in a lead cylinder or plug open at one end. The plug is stored in a lead pot and extracted by a long rod with the open end of the plug away from the operator. Larger-strength sources (up to approximately 2 curies of Co 60) can be handled in this manner. Another device has the source fixed in the pot. The exposure is made by opening the pot and exposing the source. In this type of device very large-strength sources may be used. In a more versatile system, the source is guided from the pot to the exposure position through a flexible tube. While each of these handling methods has its own advantages and disadvantages, the safety problem of personnel working in the area is not considered. For the inspection of ship welds it is desirable to have a system where men can work safely in the immediate area where an exposure is being made.

An exposure fixture was therefore developed to hold 2 curies of iridium. This device is composed of a lead container with metal hood. The isotope is exposed by removing a lead plug. The hood has the following functions: it maintains a fixed source-to-film distance and serves as a radiation shield. The general layout and the radiation leakage pattern are shown in Fig. 6. The maximum radiation one meter from the surface is 4 mr/hr.

In operation the hood is placed on one side of a ship-plate weld and film is placed on the other side. The exposure can be safely made when the personnel are within three feet of the device. This apparatus has been used successfully in the laboratory, but because it is recognized that laboratory and field conditions differ, arrangements have been made to have the apparatus field tested.

Flaw Evaluation

Radiographs require expert interpretation and evaluation; to do this successfully requires knowledge gained through past experience. The weld discontinuity found on the radiograph can be classified and graded. Reference radiographs which illustrate the graded types of flaws have been established by Government,[8] the American Society for Testing Materials,[9] and the International Institute of Welding.[10] The weld-joint designer usually establishes the acceptable grades based on experience and engineering judgment. The aim of the flaw-evaluation program conducted at Battelle Memorial Institute and Swarthmore College has been to develop information on the effect of flaws in welds. At Battelle, the weld specimen containing the flaw was welded into a nine-foot diameter sphere. This testing apparatus simulated the stress condition in the deck or hull of a ship. A brine solution was pumped into the sphere until enough pressure was built up to rupture the weld containing the flaw.[11]

The approach taken by Carpenter and Linsenmeyer at Swarthmore was to test specimens containing weld flaws with static and dynamic loading with different conditions of residual stress and at low temperatures.[12] The welding flaws were simulated to represent lack of penetration, porosity, lack of fusion and sharp internal cracks.

Summary

The inspection of a weld depends upon a method of detecting flaws and having enough information to determine the significance of the flaw on the welded structure. The information obtained by the flaw evaluation program assists in the interpretation and evaluation of the radiograph. Although other fast and inexpensive inspection methods are being investigated, radiography with isotopes has demonstrated its capabilities as a flaw-detection method.

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Process Welding of Nodular and Gray-Iron Castings

Investigation is conducted to determine which procedure is best suited to the process welding of nodular and gray cast-iron parts under normal production-welding conditions

BY BENJAMIN TOWNSHEND AND ELLIS O. PORTER

SYNOPSIS. Manufacturers of gray or nodular cast-iron parts have been plagued with the "mystery" of the process or repair welding of their products. These materials possess good fluidity, castability, are easily machined and are relatively inexpensive. Unfortunately, castings are not always perfect and occasionally minor design and machining problems arise that have to be corrected. The over-all cost of these castings to the consumer may be considerably reduced if satisfactory welding procedures are known and used.

Many excellent articles have been written concerning the weldability of cast-iron materials. In general, however, preheats over 1000° F and involved procedures have been recommended which present difficulties to the production welder when large parts are involved. During this investigation therefore, particular emphasis was placed on the determination of practicable procedures for welding restrained cast-iron parts.

A test block developed by Schumbacker and Schaeffler[1] was used to evaluate welding procedures. As a result of these tests it was determined that sound welds can be produced in restrained joints of nodular cast iron or gray cast iron using the shielded metal-arc process with the commercially available 55Ni – 45Fe electrodes and a preheat temperature of 600° F.

A buttering* technique followed by an intermediate heat treatment was found to result in weld joints comparable in strength to the base material.

The most satisfactory technique found for producing welds with a minimum of porosity was one which employed a stringer-bead technique using an arc length of about $^3/_{16}$ of an inch. A minimum amount of weld penetration is desirable and necessary to obtain porosity-free welds.

BENJAMIN TOWNSHEND is Welding Development Specialist, General Electric Co. Materials and Processes Laboratory, West Lynn, Mass., and ELLIS O. PORTER is Materials Engineer, General Electric Co., Nuclear Core Manufacturing Engineering Unit, Knolls Atomic Power Lab., Schenectady, N. Y.

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* Buttering: A term used by the British to describe the practice of depositing a pass of weld metal on the faces of a weld joint, generally for the purpose of reducing weld-metal dilution by the base material during subsequent welding.

Introduction

The ability to repair-weld nodular or gray cast iron successfully is a most important consideration to the manufacturer who is involved in the production and repair of these materials. The types of process-welding difficulties encountered generally consist of casting discontinuities, mismachined parts or undersized surfaces. Duplication of machining expenses and revision of production schedules are avoidable if the defective parts can be salvaged by welding.

Much has been written about the joining methods used for the welding of gray and nodular cast-iron parts. However, many procedures developed for the welding of cast iron which have been shown to be satisfactory under one set of conditions have later been found to be unsatisfactory under a different set of conditions. Variability in casting chemistry, electrode-material type, welding temperature, restraint and procedure have contributed to these difficulties. The inconsistency of results has created an "air of mystery" about the weldability of these materials, the answer to which, the layman is convinced, lies in "operator skill." While the "operator skill" factor cannot be discounted, the welding engineer realizes that with satisfactory procedures these materials may be joined by any competent welder.

Generally, the procedures which have been suggested as being most satisfactory either present welding difficulties (such as the maintenance of high preheat temperatures during the welding operation) or are uneconomical (studding, oxyacetylene and other patented processes). The investigation discussed in this paper was conducted to determine which procedure was best suited to the process welding of nodular and gray cast-iron parts under normal production-welding conditions. Such a procedure should, if possible, result in a welded joint which will meet all of the following requirements:

1. Provide welded joints having mechanical properties comparable to those of the base material.
2. Be economically practical.
3. Be suited to the ability of the average qualified welder.

To attain these objectives, it is necessary to know the composition and condition of the material being welded. This is not an unusual requirement for welding any material, but is mentioned because of the prevalent tendency to consider all cast irons as a single alloy. The gray and nodular cast irons selected for evaluation were those thought to be most commonly encountered throughout industry. These were: ASTM A 278 – 53, Class 30 Gray Cast Iron; and ASTM A 395 – 56 T, Grade 60-40-15 Nodular Cast Iron. No effort was made to purchase material to a controlled chemical analysis since "run of the mill" castings were desired. It is emphasized that the welding characteristics of the materials evaluated during this program do not necessarily apply to other grades of cast iron. Cast-iron types containing carbide-forming elements, having a high phosphorus content (>1),[2] larger flake size or those heat treated to obtain higher strengths and hardnesses could be expected to result in welded joints having lower strengths or greater susceptibility toward cracking.

The procedures used to investigate the welding characteristics of the two materials are discussed separately hereafter.

Procedures and Results—Gray Cast Iron

As mentioned previously, the base material evaluated was purchased to ASTM A 278 – 53, Class 30 Gray Cast Iron specifications. A detailed description of the condition of the material is given in Table 1.

The type of test plate used for evaluating the welding of both the gray and nodular cast irons is shown by Fig. 1. The test plates were cast

to the same dimensions described in the literature[1] for cast-iron plates designed to serve the same purpose. The size of the plate and weld preparation offered the high and consistent degree of restraint necessary for accurate comparisons of the characteristics of various filler materials and welding procedures. It was possible to obtain two 0.505-in. tensile bars and a cross section of the welded joint for visual and metallographic examination from each welded section. The procedures developed with this type of test plate were later applied to the welding of production castings.

Initially, welds were deposited in the test blocks with several different electrode types using the manual shielded metal-arc, gas-shielded tungsten-arc and oxyacetylene processes with a preheat and interpass temperature of approximately 600° F. The filler materials used in conjunction with the inert-arc process were obtained by stripping the flux from shielded metal-arc electrodes. A metallizing process, recommended for the purpose, was also used to deposit a high-nickel material on the cast-iron test plates, one of which was maintained at room temperature and the second at 600° F during the metallizing operation. The procedures and results of these tests are presented in Table 2.

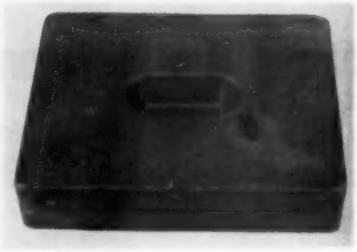

Fig. 1—Test block used to evaluate welding characteristics of nodular and gray cast irons

The welded areas in all test plates were cracked with the exception of those welded using the shielded metal-arc process with the 55Ni – 45Fe flux-coated electrode, and the test plates welded using the oxyacetylene process with both cast-iron and bronze-filler materials. As

Table 1—Description of Gray Cast Iron Used During Welding Program

Material specification: Class 30 Gray Cast Iron, ASTM A 278 – 53
Condition before welding: Stress-relief annealed
Chemical analysis, %:

Tc	3.02
Cc	0.72
Si	2.20
Mn	0.75
P	0.11
S	0.11

Graphite flake condition: Uniform distributions, random orientation; flake length generally Size 3[a]
Matrix: Pearlitic-lamellar and spherodized
Average properties: Ultimate tensile strength, 37,000 psi; hardness, 187–205 Bhn

[a] ASTM A 247.

Table 2—Results of Welding Gray-cast-iron Blocks at 600° F While Using Various Filler Materials and Welding Processes

Process	Electrode type	Appearance of welded cross section
Shielded metal-arc	55Ni – 45Fe	Sound weld
	98Ni + Co (Type A)	Weld cracks
	98Ni + Co (Type B)	Weld cracks
	68Ni – 15Cr – 11Fe	Fusion-line cracks
	14Ni – 75Cr	Fusion-line cracks
	9Ni – 29Cr	Fusion-line cracks
	66Ni – 4Mn – 20Cu	Weld cracks
Inert-gas tungsten-arc	55Ni – 45Fe	Weld cracks
	98Ni + Co (Type A)	Weld cracks
	68Ni – 15Cr – 11Fe	Weld and fusion-line cracks
	14Ni – 75Cr	Weld and fusion-line cracks
	9Ni – 29Cr	Weld and fusion-line cracks
	Low-C steel	Weld cracks
	Cast iron ($3^1/_4$ C-3 Si)	Weld cracks
Oxyacetylene[a]	Cast iron ($3^1/_4$ C-3 Si)	Sound weld
	60Cu – 35Zn	Sound braze
Metallizing[a]	97.5Ni – 1Co	Poor bond to cast iron

[a] Actual preheat was greater than 600° F in samples that were welded using the oxyacetylene process and less for one of the metallized samples.

Table 3—Welding of Gray-Cast-Iron Test Plates

No. of samples welded	Welding process	Interpass temperature, ° F	Electrode material	Postweld treatment	Condition varied	Average tensile strength, psi	Location of tensile fracture
1	Shielded metal-arc	70	55Ni – 45Fe	...	Plate temperature	Cracked during welding	...
2	Shielded metal-arc	300	55Ni – 45Fe	1200° F, 2–4 hr	Plate temperature	Nil	...
5	Shielded metal-arc	550–600	55Ni – 45Fe	1200° F, 2–4 hr	Medium arc length ($^3/_{16}$ in.)	36,100	Fusion line
2	Shielded metal-arc	600	55Ni – 45Fe	1200° F, 2–4 hr	Long arc ($^1/_4$–$^5/_{16}$ in.)	29,950	Voids at fusion line
1	Shielded metal-arc	600	55Ni – 45Fe	1200° F, 2–4 hr	Short arc ($^1/_{16}$–$^1/_8$ in.)	36,250	Fusion line and weld
4	Shielded metal-arc	900	55Ni – 45Fe	1200° F, 2–4 hr	Temperature	33,250	Fusion line voids and base metal
1	Oxyacetylene	Estimated to be 1300	Cast iron	None	None	23,500	Fusion zone
1	Oxyacetylene	900–1200	Bronze	None	Grit—blast surface	26,250	Bronze—interface
1	Oxyacetylene	900–1200	Bronze	None	Ground surface	26,500	Bronze—interface

a result of these tests, work was discontinued on all electrode types except the 55Ni – 45Fe deposited using the shielded metal-arc process. The test plates welded using the oxyacetylene process were made to determine the properties of gas-welded joints in gray cast iron.

Several welds were deposited in the test-block grooves with the 55Ni – 45Fe electrode using various welding procedures and techniques. These tests were made to determine the relative sensitivity of the procedure and are discussed in more detail later in the text. After completion of these tests, cross-weld tensile specimens were prepared and tested for joint efficiency. Results of these tests are presented in Table 3.

In addition to the investigation of conventional welding methods, the effects of buttering, followed by an intermediate heat treatment, were studied. It was expected that some of the difficulties inherent with the process welding of large cast-iron parts could be simplified by the use of such a procedure.

Discussion of Results—Gray Cast Iron

Failure of the welds deposited by the shielded metal-arc process using high-nickel and copper-nickel flux-coated electrodes was apparently caused by a hot-short condition of the weld which, in turn, was caused by base metal contamination of the weld. The effect of sulfur on the hot shortness of nickel materials is well known. This point, however, was not investigated since it was beyond the scope of this investigation. This type of cracking was also characteristic of welds deposited using the inert-gas tungsten-arc process with all filler-metal types.

The welds made using the Cr-Ni filler materials had higher yield strengths than the gray cast iron at room and elevated temperatures and the joint generally failed in the heat-affected zone as a result of the combined weld contraction and transformation stresses.

The success of shielded metal-arc welding with the 55Ni – 45Fe electrodes was attributed to a combination of factors.

1. Primarily, the yield strength of the weld metal at both room and elevated temperatures is low, which permits the accommodation of stress in the weld as well as in the base material.

2. The electrode has a higher percentage of Fe and probably is not as sensitive to base-metal contamination and hot-shortness.

3. During metal-arc welding the molten metal is very sluggish, being ejected in large drops as a result of gravity rather than arc force. This limits dilution of the base material since the welding pool is never very fluid. The same material as deposited using the inert-gas method developed weld cracking. The molten pool in this case was very fluid and active. Weld penetration was greater and a larger percentage of the weld was composed of the base material which, of course, increased weld contamination and cracking susceptibility. In addition, the inert-gas welds resulted in a rippled weld bead which was in contrast to the relatively smooth bead produced with the shielded metal-arc process. The different appearance of the beads suggests a difference in freezing patterns which could in itself be responsible for the different results.

Effect of Preheat

Preliminary evaluation of bead-on-plate tests using the 55Ni – 45Fe flux-covered electrodes indicated that cracking in the welded area could not be avoided on parts maintained at temperatures below 300° F during the welding operation. While the welds in the tensile bars appeared to be sound, the specimens failed in the fusion zone under extremely low tensile loading. Tensile specimens of welds made at 600 and 900° F failed at loads slightly below the strength of the base metal in the fusion zone and base metal, respectively.

The use of preheats at and above 600° F and varied welding techniques had little effect on the tensile strength of the welded joint except in the case where a long arc was used. Variation in procedures tested and results are shown in Table 3. The long arc resulted in a

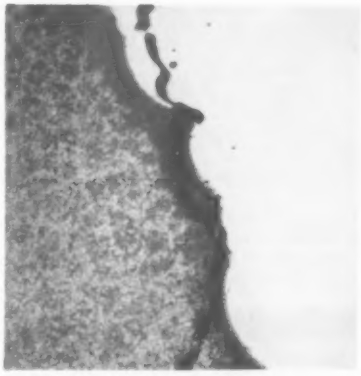

Fig. 2A—Fracture in gray-cast-iron sample welded at 300° F; 2% Nital etch. × 5

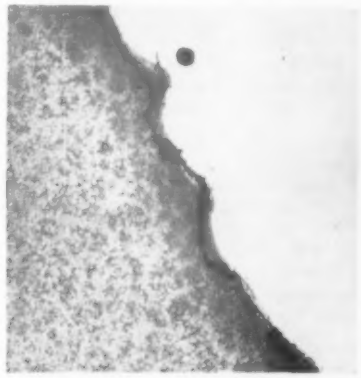

Fig. 3A—Gray cast iron welded at 600° F. Failed as a result of tensile testing; 2% Nital etch. × 5

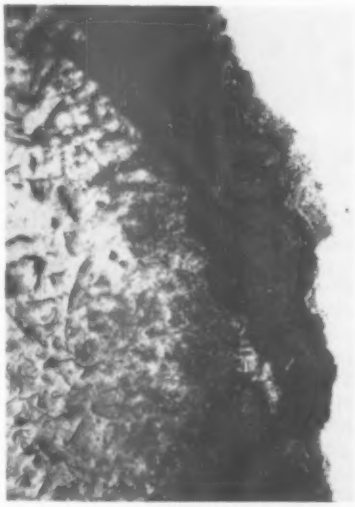

Fig. 2B—Portion of fracture at higher magnification; 2% Nital etch. × 50. (Reduced by 35% upon reproduction)

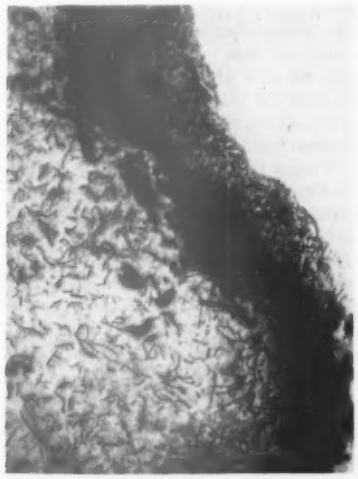

Fig. 3B—Typical area of fracture; 2% Nital etch. × 50. (Reduced by 35% upon reproduction)

Table 4—Intermediate Heat Treatment of Welded Gray-cast-iron Test Plates

Material contacted by weld	Temperature of part during welding	Heat treatment	Tensile strength, psi	Fracture location
(a) Weld to base metal (buttered portion)	550–650° F	1500° F/4 hr.	29,750	Base metal
(b) Weld to weld (remainder)	Room temperature	None	24,250	Base metal
(a) Weld to base metal (buttered portion)	550–650° F	1200° F/2 hr.	32,750	Weld (porosity)
(b) Weld to weld (remainder)	Room temperature	None	41,250	Base metal
(a) Weld to base metal (buttered portion)	550–650° F	1200° F/2 hr.	28,250	Weld (porosity)
(b) Weld to weld	550–650° F	None	40,500	Base metal

Table 5—Description of Nodular Cast Iron Used During Welding Program

Material specifications: 60-40-15 nodular cast iron; ASTM A 395 – 56 T
Condition before welding: Ferritize annealed
Chemical analysis, %:

Tc	3.55
Cc	0.28
Mn	0.60
Si	2.37
P	0.033
S	0.010

Matrix: Ferrite—approximately 15% pearlite
Average properties:

Tensile strength, psi	68,000
Yield strength, psi	31,000
Elongation, %	17
Brinell hardness number, max.	180

number of weld defects which accounted for the somewhat lower tensile strength of sample ST-10.

After tensile testing, the specimens were subjected to metallographic examination to determine the mode of failure. Figures 2A and 2B show the progress of the crack in the heat-affected zone of the weld made at 300° F. Figures 3A and 3B, 4A and 4B, show the same conditions for tensile failures in typical samples welded at 600 and 900° F, respectively.

Visual examination of the sample welded at 300° F revealed that extensive microcracking had apparently taken place during welding. The only sound portion of the joint prior to testing was near the surface of the specimen at the point where the crack detoured into the weld. Progress of the crack may have been arrested by the defect that can be seen at that point in Fig. 2A. The path of fracture, however, closely paralleled the fusion line as shown in the macrograph of Fig. 2B.

The tensile failure of the weld made at 600° F preheat is also almost completely in the heat-affected zone. However, failure took place at a load only slightly below the strength of the base metal. The heat-affected zone in this sample appeared to have essentially the same microstructure as that noted in the sample welded at 300° F. The use of the 600° F preheat was apparently high enough when combined with the heat of the welding operation to permit plastic flow of both the weld and base materials, prior to cooling to the point where high contractual stresses would be exerted on the base material. Tensile stresses exerted on the heat-affected zone are not necessarily low at 600° F, but they were not high enough to cause cracking. The subsequent heat treatment (2–4 hr at 1200° F), of course, relieved the tensile stresses and restored the welded area to near base-metal strength and ductility.

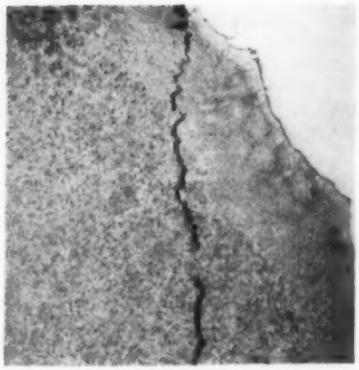

Fig. 4A—Gray cast iron welded at 900° F and fractured as a result of tensile testing. Note location of fracture as compared to Figs. 2A and 3A, 2% Nital etch. × 5

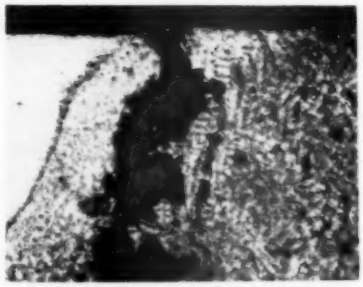

Fig. 4B—Probable area of tensile fracture; 2% Nital etch. × 50. (Reduced by 50% upon reproduction)

Examination of the sample welded at 900° F showed that the microstructure of the heat-affected zone was completely different from samples welded at 300 and 600° F. As may be seen in Fig. 4A, the failure of the tensile test specimen is not closely associated with the heat-affected zone except possibly for the initiation of failure. The heat-affected zone is composed of fine, interconnected graphite nodules, with less pearlite and more ferrite than was present in the same areas of the 300 and 600° F specimens. With the preheat of 900° F, the heat-affected zone is subjected to a time-temperature cycle which permits the carbon to go into solution and precipitate out at nucleated areas in the form of fine graphite nodules.

Variation of Shielded Metal-arc Welding Techniques

Welding techniques were varied to determine how sensitive the procedure was to operator techniques. It was found that what would be classed as a normal welding procedure (i.e., short arc, no weaving) often resulted in welds containing an excessive amount of porosity. In addition, the operating characteristics of the 55Ni – 45Fe electrode are such that with the short arc, the welds tend to be high-crowned which leads to slag entrapment and weld voids. Smaller welds, made by increasing travel speed, appeared to have less porosity but bead shape was still poor.

It was possible to reduce weld convexity by weaving. However, the increased heat input increased weld penetration and resulted in greater weld porosity.

Lengthening the arc to about $^{3}/_{16}$ of an inch resulted in welds having a flatter contour and reduced weld porosity and base-metal dilution.

Buttering Followed by Intermediate Heat Treatment

The effect of intermediate heat treatment was evaluated for use when welding large grooves and when maintenance of heat in the weldment is impossible or difficult. The procedure used for evaluation was as discussed hereafter. First, a single-depth weld pass was deposited over the entire surfaces of three grooves in the standard gray-cast-

iron test plates. The temperature of the plates varied between 550 and 650° F during the welding operation. The plates were allowed to cool to room temperature after completion of welding. Next, one of the plates was heated to 1500° F and held for 2 hr. The other two were stress relieved at 1200° F for 2 hr; all were furnace cooled to approximately 600° F. Finally, one of the stress-relieved samples and the annealed sample was welded to completion using a 70 to 100° F interpass temperature. The second stress-relieved sample was welded at 600° F. None of the samples were given a postweld heat treatment. Use of low interpass temperatures and elimination of postweld treatment in these samples was to learn if a single-depth butter pass provided sufficient thermal insulation to the base metal during welding.

The tensile results of bars machined from each welded plate are given in Table 4. The tensile values and location of fracture indicated that the full-anneal heat treatment had significantly lowered the strength of the cast-iron base material. The strengths of the samples that were stress relieved after the buttering passes were considerably higher than those that had been annealed, except for the bars that contained excessive weld porosity.

Procedures and Results—Nodular Cast Iron

Fully annealed material purchased to ASTM A 395 – 56 T, Grade 60-40-15 specifications was the base material used for this portion of the investigation. The type of test plate used to evaluate the gray cast iron was also used for evaluation of the welding of nodular iron. Chemical analysis, mechanical properties and a description of the metallographic structure of the material are contained in Table 5.

The effect of using the buttering technique (previously described for welding gray cast iron) was also evaluated for the welding of nodular cast iron. In addition to trial of the "buttering" technique, one test plate was welded and tested without the benefit of any stress-relief heat treatment.

All welds were made with preheat and interpass temperatures of 550 to 600° F and allowed to cool slowly to room temperature on completion of welding. One of the test plates that was buttered was given a ferritizing anneal at 1650° F after the buttering operation. It was then preheated to 550–650° F and welding was completed. After completion of welding, the plate was given a 15-hr stress relief at 1200° F.

The second test plate that was buttered was given a 2-hr stress relief after "buttering" at 1200° F and a 15-hr stress relief at 1200° F after completion of welding.

Results of tensile tests of these joints are presented in Table 6.

Discussion of Results—Nodular Cast Iron

While it is known that nodular cast iron is less crack-sensitive than gray cast iron from a welding standpoint, the problems introduced by the presence of large amounts of carbon and discontinuous matrices exist with both materials. Nodular cast iron differs from gray cast iron in that small amounts of magnesium, added to the melt, cause the graphite to take the form of small nodules or spheroids rather than flakes. This results in a stronger, tougher, more ductile material. However, the heat of the welding process results in a hard brittle zone of untempered martensite and cementite in the heat-affected zone of the base material. In addition, the high-carbon content results in weld-metal contamination. Diffusion of carbon into the portion of the weld adjacent to the fusion line produces a hard carbide structure which is quite difficult to machine.

The as-welded structure is shown in Fig. 5. Knoop-hardness readings were taken across the weld, fusion zone, heat-affected zone and base metal. These hardnesses are presented in Table 7. The relative difference can be seen, however, in Fig. 5. Figure 6 is a photomicro-

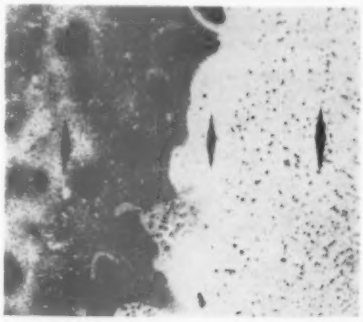

Fig. 5—Fusion area of 55Ni – 45Fe weld and nodular-iron base metal; 2% Nital etch; × 250. (Reduced by 60% upon reproduction)

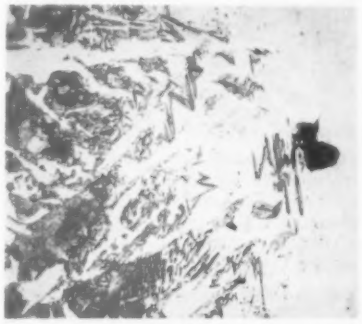

Fig. 6—Area at weld interface of nodular iron in the as-welded condition; 2% Nital etch; × 1000. (Reduced by 55% upon reproduction)

Table 6—Intermediate Heat Treatment of Welded Nodular-iron Test Plates

No. of samples	Material contacted by weld	Heat treatment	Temperature, ° F, of part during welding	Average tensile strength, psi	Average yield strength, psi	Fracture location
2	(a) Weld to base metal (buttered portion)	FHT[a]	550–650	52,000	30,750	Weld
				49,000	32,250	Weld
	(b) Weld to weld (remainder)	1200° F/15 hr[b]	550–650	53,000	30,750	Weld
				51,750	30,750	Weld
3	(a) Weld to base metal (buttered portion)	1200° F/2 hr	550–650	57,250	34,500	Fractures caused by defect in base metal
				58,750	33,000	
				55,500	34,500	
	(b) Weld to weld (remainder)	1200° F/15 hr	550–650	58,750	36,000	
				54,000	33,000	
				47,750	32,250	Weld, porosity
1	Conventional welding procedure	None	550–650	49,000	...	Weld, porosity
				43,250	...	Weld, porosity

[a] FHT (Ferritizing heat treatment) = 1650° F/2 hr; cool 200° F/hr to 1275° F—hold 4 hr; furnace cool.
[b] The 15-hr cycle was a result of furnace malfunction, only 2 hr hold was intended.

Table 7—Knoop Hardness (500 Gr Load) Survey of Nodular-iron Weld Area

Heat-treated condition	Area tested	Depth of area tested, in.[a]	KHN 500 range in area[b]
As-welded	Portion of weld adjacent to base metal	0.010	390–726
	Heat-affected zone	0.060	271–455
1200° F/2 hr (stress-relief anneal)	Portion of weld adjacent to base metal	0.008	274–564
	Heat-affected zone	0.060	190–511
1650° F (ferritizing anneal)	Portion of weld adjacent to base metal	0.010	222–312
	Position formerly occupied by heat-affected zone	0.020	185–316

[a] Depth of area as measured from fusion line.
[b] Based on an average of several areas tested.

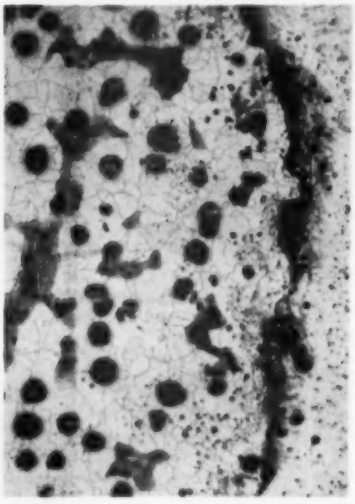

Fig. 7—Welded nodular-iron sample showing effect of ferritizing anneal treatment on the welded area. Note elimination of pearlite in base metal; 2% Nital etch; × 1000. (Reduced by 35% upon reproduction)

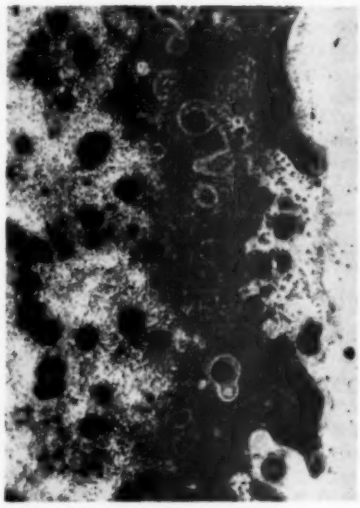

Fig. 9—Welded nodular-iron sample stress relieved after the buttering operation; 2% Nital etch; × 100. (Reduced by 35% upon reproduction)

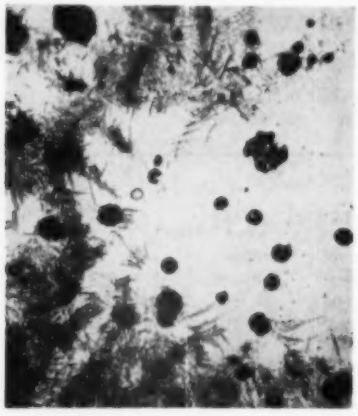

Fig. 8—Pearlitic area in weld after ferritizing anneal; 2% Nital etch; × 1000. (Reduced by 50% upon reproduction)

graph taken at × 1000 of the carbide area that extends into the weld seen in Fig. 5. The structures seen in Fig. 6 are untempered martensite and cementite in an austenitic matrix.

Figures 7 and 8 show the microstructure of weld and heat-affected zone at × 100 and the fusion line area at × 1000, respectively, after the 1650° F ferritizing-anneal. As may be seen in Fig. 7, the graphite is almost completely in the spheroidal form. An area of fine pearlite exists at the fusion line just inside of the weld.

Figure 9 is a photomicrograph of the sample that was stress relieved after buttering and after completion of welding. The structure appears to be the same as that shown in Fig. 5. The hardness of the heat-affected zone was, however, considerably lower than that of the as-welded sample. The comparison is shown in Table 7.

The strength of the samples that had been ferritize annealed after buttering was uniform and all samples failed in the weld during testing. The higher tensile strengths shown for the six stress-relieved samples do not reflect the true value of the joint because all samples (with the exception of one) failed in the unaffected base metal. The two tensile specimens taken from the plate that had no postheat treatment failed in the weld at lower loads than the samples which received an intermediate heat treatment. It was obvious from examination of all samples which failed in the welds that weld porosity had a significant effect on the mechanical properties of the welded joint.

Conclusions*

1. Both gray cast iron to ASTM A278–33, and nodular cast iron to ASTM A395–56T specifications can be welded successfully using the shielded metal-arc process, 55Ni – 45Fe electrodes with a preheat and interpass temperature of 600° F.

2. Buttering of the surface of gray-cast-iron or nodular-cast-iron joints with 55Ni – 45Fe electrodes at 600° F preheat, followed by stress relief at 1200° F, or a full anneal, permits process welding of the remainder of the joint to be carried out at room temperature.

3. The procedure described in Par. 2, results in nodular-cast-iron and gray-cast-iron weld joints comparable in strength to that of the base metals, provided care is taken to prevent the occurrence of weld porosity.

4. The most satisfactory technique found for producing welds with a minimum of porosity was a stringer-bead technique with which an arc length of about $^3/_{16}$ in. was maintained.

Acknowledgments

The authors wish to express their appreciation to co-workers in the Turbine Materials and Processes Laboratory for their helpful suggestions and to Francis E. Bates for his assistance on the metallographical aspects throughout this work.

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2. Dunn, F., and Morton, G. E., "The Welding of Flake Graphite Cast Irons, with Particular Reference to the Mechanical Properties of Butt Welded Joints," *Jnl. Research and Development*, **6**, Research Report No. 445, 364–402.

* When this paper was written the authors included information and expressed opinions believed to be correct and reliable. Because of the constant advance of technical knowledge, the widely differing conditions of possible specific applications and the possibility of misapplication, any application of the contents of this paper must be at the sole discretion and responsibility of the user.

Welding of Reinforcing Bars for Concrete Construction

Purpose of test program was to investigate the applicability of arc welding to the joining of reinforcing bars selected from random lots and representing hard, intermediate and structural grades

BY J. F. RUDY, F. SUYAMA AND H. SCHWARTZBART

ABSTRACT. An investigation of the welding of reinforcing bars has been conducted on random lots, obtained from eleven different suppliers, and representing hard, intermediate and structural grades, in three different bar sizes, embracing a range of chemical composition as follows:

Carbon ..... from 0.21% to 0.84%
Manganese ..... up to 1.67%
Phosphorus ..... up to 0.081%
Sulfur ..... up to 0.067%

Although the sampling technique utilized in obtaining the material for this study did include bars from several principal domestic sources and from all reinforcing bar grades, it should be noted that the chemical composition of bars encountered in service may be outside the range investigated herein.

Several geometries of both lap and butt welds were investigated, totaling approximately 550 weldments.

A welding procedure is presented with which strengths up to 75,000 psi to 80,000 psi have been obtained in butt welds on bars of all analyses investigated, except structural grade, where 90% joint efficiency was obtained. These values represent joint efficiencies approaching 100% for intermediate and structural-grade bars, and 60 to 80% for the hard-grade bars, based on the ultimate strength as 100% efficient. If the yield point, which is the figure used for design calculations, is adopted as the basis for joint efficiency, these values run from ~105% for hard-grade steels up to ~175% for the intermediate and structural grades.

The procedures involved utilize either E7016 electrodes (70,000 psi ultimate, low hydrogen) or its iron-powder modification. The joint geometries used are conventional, with no preheat requirement. Limited evaluation of the procedure on bars which had been cooled to 0° F indicated no deleterious effects of low temperature.

J. F. RUDY, F. SUYAMA and H. SCHWARTZBART are associated with the Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.

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Introduction

Probably almost as old as welding itself is the knowledge that the difficulty in obtaining sound ductile welds increases with increasing carbon content of the steels to be joined. The reason for this difference in the reaction of steels to the welding thermal cycle is the higher hardenability of higher-carbon steels which increases the likelihood of martensite formation at practical cooling rates. The accepted cure for this difficulty is to control the rate of cooling from the welding temperature by decreasing the thermal gradient ("preheating" the base metal). This method is known to be effective. However, the precaution of preheating to prevent cracking is not necessarily warranted solely by the fact of higher-carbon base metal. The necessity for preheating presupposes, in addition to increased hardenability, (1) a base-metal thermal reservoir of adequate capacity (sufficient metal mass) to maintain a steep thermal gradient, and (2) sufficient restraint to allow crack-inducing stresses to be set up by temperature differential. Thus, the presence of high carbon (or other hardenability increasers) does not necessarily dictate a need for preheating.

In addition to increased hardenability elements, the "tramp elements" phosphorus and sulfur must also be considered as possible problem sources, since their presence promotes "hot-short" cracking by providing a low-melting grain-boundary constituent. The tolerance for these elements also depends on restraint and thermal-stress considerations since it is a load at the hot-short temperature which causes cracking.

These chemistry-weldability considerations are appropriate to the welding of concrete reinforcing bars. The requirement for welding of reinforcing bars in concrete structures has been, and may continue to be, a relatively minor one, due to the prevalence of either mechanical fastening or of obtaining the joint by transmission of shear stresses through the concrete from the deformations of one bar to the deformations of the other bar. The latter method is by far the most widely incorporated but suffers the disadvantage of requiring an overlap between the bars in question.

In new structures, the overlap requirement often necessitates larger column cross sections in order to provide room for the steel. This provides an economic motive for a butt-welded joint. However, the impetus for sponsorship of this study came from the highway building program which calls for the enlargement of old concrete bridges. This program requires that attachments be made to exposed bars in the original structure. These bars are of unknown composition. This attachment might be accomplished by welding.

The purpose of this program, therefore, was to investigate the applicability of arc welding to the joining of reinforcing bars. In evaluating the mechanical results of this study, it is understood that reinforced concrete design is based on yield-point calculations and that the structure is likely to fail by concrete deterioration if the steel ever yields in service. Therefore, a weld that allows the steel to be loaded to its yield point is adequate.

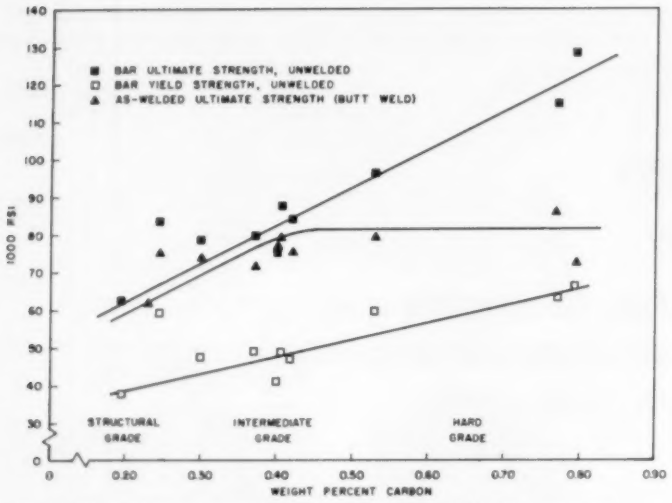


Fig. 1—Butt-welded vs. unwelded properties, No. 11 ($1^3/_8$ in. diam) bar

Steels Studied

Reinforcing bars are classified as either structural, intermediate, or hard grade from low- to high-carbon content. The separation is made on the basis of a yield-strength rating which places the dividing lines at approximately 0.30% carbon (structural to intermediate grade) and 0.50% carbon (intermediate to hard grade). Steels are produced for these various grade bars by several methods. In addition to the primary steel-production sources—open hearth, Bessemer and electric furnace—there are the secondary sources, re-rolled rail steel and re-rolled axle steel. The primary-source steel is usually intermediate grade but could possibly be any one of the three grades. Rail steel usually falls in the hard-grade class, and axle steel may be either hard or intermediate grade.

The reinforcing bars for this program were obtained from eleven different suppliers at random, and included primary and secondary sources, hard, intermediate and structural grades, and three sizes No. 4 ($^4/_8$ in. diam), No. 8 ($^8/_8$ in. diam), and No. 11 ($^{11}/_8$ in. diam). Most of the work was done on the two larger sizes since their higher mass offered the more critical condition. The chemical compositions are presented in Table 1. It is seen from the Table that the composition range represented is: carbon—from 0.21 to 0.84%, manganese—up to 1.67%, phosphorus—up to 0.081%, and sulfur—up to 0.067%. Although the random sampling technique utilized in obtaining the material for this study did include bars from several principal domestic sources and from all reinforcing bar grades, it should be noted that the chemical composition of bars encountered in service may lie outside the range investigated. To what extent this is true would require a large statistical sampling program, which lies outside the scope of the present investigation. Such information could possibly be provided by the American Iron and Steel Institute or by the steel companies.

Discussion of Welding Results

Butt Welds

The mechanical properties of the weldments made in the various grades, types and heats of reinforcing bars can best be discussed by referring to the plotted data in Figs. 1, 2, 3, 4 and 7. Figures 1 and 2 summarize the butt-welding results when no joint reinforcing was used. These plots compare the as-welded strength with the yield and ultimate strengths of the base-metal bars containing no weld. As the bar strength increases with increasing carbon content, the weld strength increases in a parallel fashion at slightly lower strength (generally

Table 1—Chemical Composition of Steels

Steel (code)[a]	Bar diameter x $^1/_8$ in.	Type of steel	Chemical analysis, wt %				Mechanical properties		
			Carbon	Manganese	Phosphorus	Sulfur	% Elongation, in 8 in.	Yield strength, ksi	Ultimate tensile strength, ksi
Hd.-1	8	Rail[b]	0.84	0.82	0.030	0.027	7.2	68.0	125.7
Hd.-2	11	Rail[b]	0.77	0.79	0.011	0.026	...	62.5	114.3
Hd.-3	8	Rail[b]	0.64	1.50	0.019	0.028	...	68.0	138.0
	11		0.79	0.75	0.016	0.034	...	66.0	128.0
Hd.-4	11	Open hearth	0.53	0.91	0.019	0.031	11.9	59.0	95.8
Int.-1	8	Open hearth	0.35	0.58	0.026	0.046	25.6	46.8	77.8
	11		0.24	1.67	0.015	0.030	28.0	59.0	83.3
Int.-2	8	Open hearth	0.44	0.51	0.017	0.035	18.8	45.4	77.8
	11		0.42	0.67	0.012	0.030	17.2	46.8	83.3
Int.-3	8	Axle[b]	0.41	0.52	0.043	0.067	24.8	44.0	74.7
	11		0.40	0.48	0.016	0.026	28.1	40.8	74.7
Int.-4	8	Open hearth	0.41	0.52	0.012	0.043	23.4	46.8	81.1
	11		0.41	0.77	0.012	0.034	21.9	48.4	87.2
Int.-5	8	Electric furnace	0.36	0.56	0.036	0.045	22.2	43.9	77.5
	11		0.38	0.52	0.024	0.042	18.7	45.8	79.4
Int.-6	8	Bessemer	0.35	0.44	0.075	0.038	22.2	52.5	85.0
	11		0.30	0.49	0.081	0.036	21.9	47.3	78.5
Str.-1	8	Open hearth	0.21	0.99	0.006	0.031	30.6	38.0	64.8
	11		0.23	0.44	0.006	0.026	26.6	37.2	62.0

[a] Hd.—Hard, Int.—Intermediate, Str.—Structural. [b] Rerolled.

about 5 to 10% lower). At approximately 0.040 to 0.050% carbon, however, the base-metal ultimate strength continues to rise while the as-welded strength levels off at approximately 80,000 psi. This point of departure is at the intermediate grade to hard-grade steel-classification change. Since the electrodes for joining the bars were an AWS E 70XX type, this behavior was expected. (The weld-metal deposit is designed to a nominal minimum tensile strength of 70,000 psi.)

The practical meaning of these data can only be appreciated with an understanding of the design considerations of reinforced-concrete construction. The design calculations are all based on the yield point of the reinforcing steel, with appropriate safety factors applied to yield-point figures instead of to ultimate strength. In reinforcing concrete construction this is warranted by the inability of the brittle concrete to follow any appreciable (i.e., plastic) flow. Thus, the fact that the weld joint can develop strength levels in excess of the bar yield points over the whole range of carbon contents is most significant (Figs. 1 and 2).

Therefore, the behavior illustrated by the plots can be considered satisfactory for the use intended. Thus, an electrode choice for any reinforcing bar might be partially dictated by the requirement for its nominal minimum strength to be comfortably in excess of the yield point of the reinforcing bars. The welding procedures used are presented below.

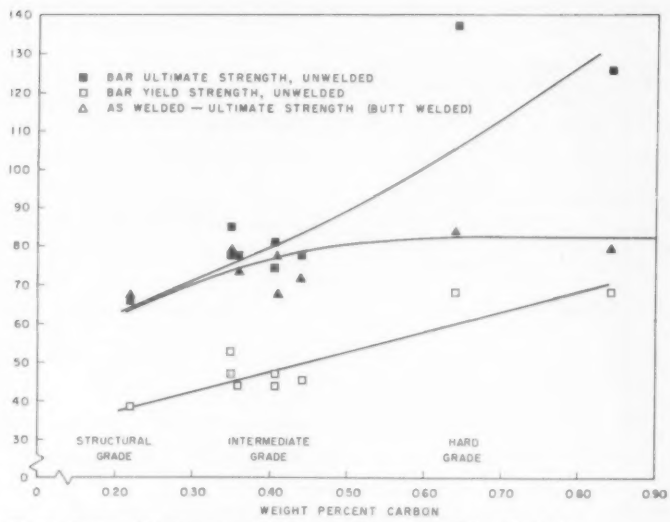


Fig. 2—Butt-welded vs. unwelded properties, No. 8 (1 in. diam) bar

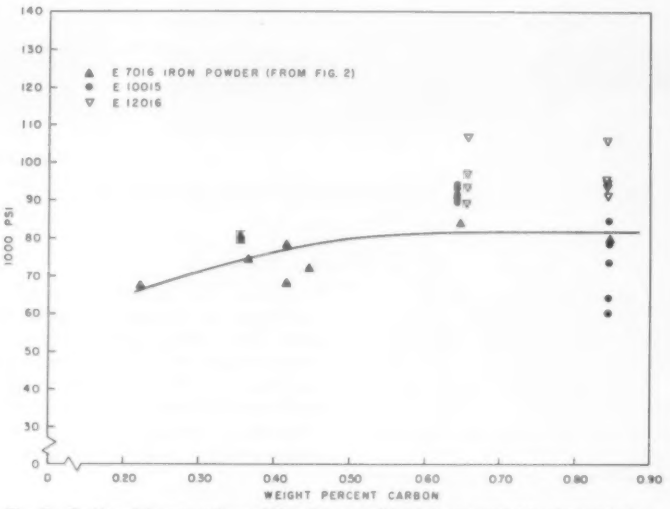


Fig. 3—Butt-weld properties of No. 8 bars with higher-strength electrodes

Higher-strength Electrodes

Even though the above argument points out the acceptability of the E70XX electrode types for this application, additional effort was directed toward determining the extent of ultimate strength improvement that can be realized by substituting a higher-strength electrode. The majority of the fractures with the lower-strength electrodes was associated with both the weld metal and the heat-affected zone adjacent thereto. Thus, the possibility existed for a stronger weld-metal deposit to increase the joint strength. Figure 3 is a plot of mechanical strength vs. carbon content for three electrode strength levels. Some improvement is shown although the nominal minimum strengths (100,000 and 120,000 psi) were not obtained due to initiation of fracture in the heat-affected zones of the bars. The scatter of strength values with the 0.83% carbon heat indicates that the minor strength increase was obtained at the cost of an increased susceptibility to weld-area flaws. The nature of these scatter-causing flaws was not determined but would be expected to be associated with the higher strength and reduced ductility of the weld deposit.

Weld-joint Reinforcing

Since the aesthetic properties of reinforcing joints are completely obscured by the concrete encasement, construction practice sometimes includes a means of joint reinforcement as an added safety factor. Figure 4 compares two reinforced joint designs with the simple butt weld. The angle-iron backup joint (shown in Fig. 5) consists of a butt weld plus an addition to the weld-area cross section obtained by double-fillet welding an angle to the bar for a distance of 2 bar diameters in either direction. The strength of the hard-grade steels was improved by this design.

The strap backup merely serves a function similar to the backup ring used for pipe welding, providing a support for root-pass penetration. This design (shown in Fig. 5) also resulted in general strength increases, although accompanying slag-removal difficulties caused some low values due to slag-entrapment flaws.

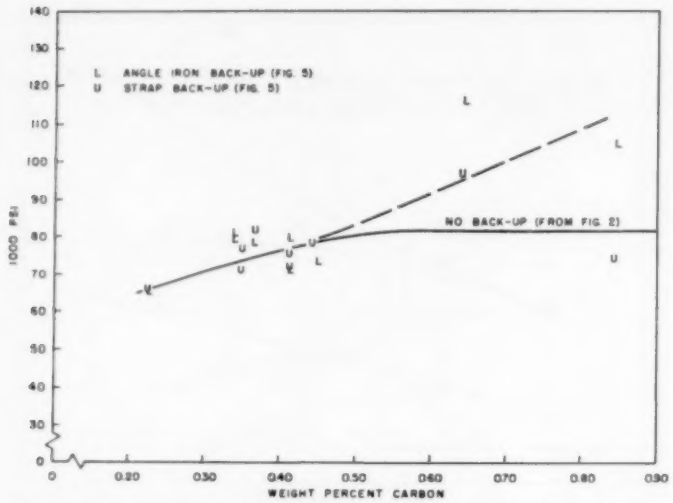


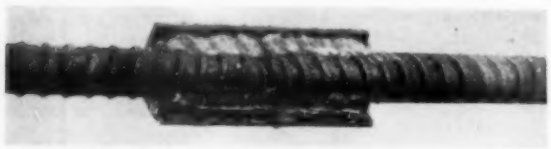
Fig. 4—Comparison of straight butt welds with welds made with angle-iron and strap reinforcement. No. 8 bars, E7016 electrodes

several passes only one bar diameter long. This necessitates more interpass cleaning of slag. Fit-up is also less critical with the lap joint, and weld joints can be reinforced by increasing the overlap distance.

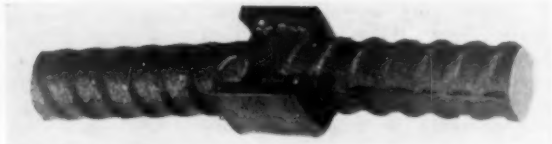
Figure 7 gives the comparative data between various lap-weld joint designs (note code system) and the butt welds discussed previously (Fig. 2). All of the unmodified lap welds failed at strengths considerably below the butt-weld curve. This is explained by considering the additivity of the tensile load and the bending load due to eccentricity during tension testing. A typical lap-weld test result is illustrated schematically in Fig. 8.

Lap Welds—Encased in Concrete

Since the observed eccentricity effects may be alleviated by concrete encasement in service, an experiment was performed wherein several lap welds were made and the joints subsequently encased in a concrete cylinder, as shown in Fig. 9. These data show an improvement over the strengths of the unrestrained weldments in Fig. 7. However, the strength of the hard-grade weldment was still less than the yield strength of the base metal, and all welds were considerably weaker than corresponding butt welds. Figure 10 shows a modification of the lap weld. The end fillets were added to reduce the concentration of the eccentricity stresses. These data show an improvement in strength, as seen in Fig. 7. A final cursory attempt was made to improve the mechanical properties of lap welds by reducing the eccentricity. This was accomplished by preparing the bars as shown in Fig. 11, incorporating a shallow 15-deg bevel which moves the axes of the two bars much closer to a concentric alignment. Only a few welds were tested with this design, but the tensile results were approximately 140% of hard-grade yield point or 104,000 psi. The weld time is considerably reduced from the butt-weld requirement (fewer passes), and the 15-deg bevel is no more difficult to accomplish by oxygen cutting than



(a) Angle-iron backup



(b) Strap backup

Fig. 5—Weld joints reinforced by angle-iron and mild-steel backup strap. × 1/2

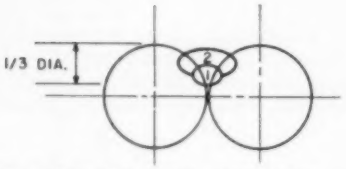


Fig. 6—Typical lap-weld cross section—2 passes

Lap Welds

There are several possible advantages to joining two reinforcing bars by a fillet weld between overlapped bars as shown schematically in Fig. 6. Welding time is shorter because sufficient weld metal can be deposited during one or two longer passes while a butt weld requires

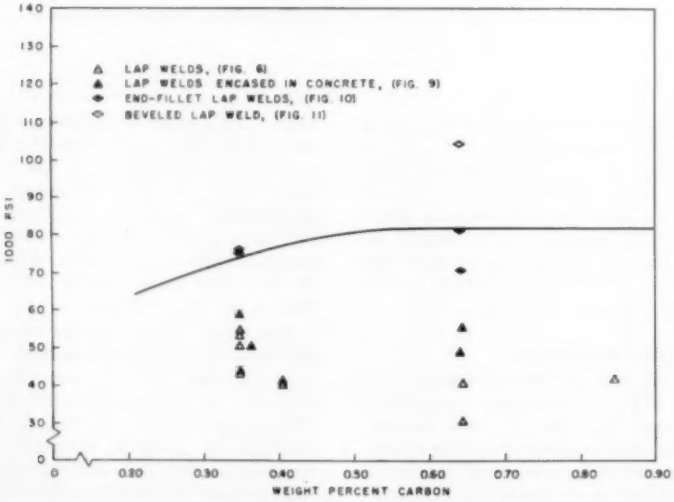

LAP WELDS, (FIG. 6)
LAP WELDS ENCASED IN CONCRETE, (FIG. 9)
END-FILLET LAP WELDS, (FIG. 10)
BEVELED LAP WELD, (FIG. 11)
1000 PSI
WEIGHT PERCENT CARBON

Fig. 7—Comparison of four lap-weld joint designs. No. 8 bars, E7016 electrodes

a 45-deg double bevel for the butt weld.

Welding Procedures

Having discussed the mechanical properties obtained in weldments in reinforcing bars, it remains to present the procedural details with which the weldments were accomplished. Table 2 gives a summation of these data for butt welding. Butt welds are not practical on the No. 4 bars because of operator difficulties with such a small joint. For the other sizes, both single- and double-vee joint designs were employed. Bevel joints could also have been adapted, the only drawback being less space for the operator to manipulate the electrode in the root of the weld, hence increased operator skill requirements.

The electrode employed was a low-hydrogen type (lime-coated) which has been reported in the literature to have a lower propensity for root cracking in the higher hardenability steels. However, no other types of electrodes were tested so no negative conclusions can be drawn. With the E7016 electrode (or its iron-powder modification) no cracking was visually observed in any specimen welded during the study, including several deposits on bars as cold as 0° F. Higher-strength, low-hydrogen electrodes (E10015 and E-12016) were investigated with results previously discussed (Fig. 3). No macrocracks were observed with these higher-strength deposits at normal ambient temperatures; however, at temperatures of 32 and 0° F a root-pass cracking tendency was observed. Thus the best results were obtained with the E7016 types.

All end preparation was done by oxygen cutting. Cleaning after cutting consisted only of manual wire brushing to remove heavy, loose scale.

Welding currents, as reported in Table 2, were arrived at by actual measurement of those values which were observed to provide the most satisfactory weld-puddle behavior. Initially in the program, an effort was made to introduce as much heat as could be controlled into the weld area for the purpose of "preheating" the base metal for subsequent passes. However, later observations showed this precaution to be unnecessary. With this procedure the base-metal temperature in the weld area was approximately 200° F just prior to the second bead, and 300° F prior to all subsequent beads.

Table 3 gives procedure data for lap welds. The user of this joint

Table 2—Vertical Butt Welds

Bar diameter x 1/8 in.	Electrode, AWS	End preparation	Included angle, deg	Pass sequence	Current (DCSP)[b] amp: Root pass	Current (DCSP)[b] amp: Subsequent passes
4		Not recommended			...	...
8	E7016[a]	Single V	90		140	130
8	E7016[a]	Double V	90		140	130
11	E7016[a]	Single V (only when access is limited)	90		140	130
11	E7016[a]	Double V	90		140	130

[a] Either E7016 or its iron-powder modification may be used, 1/8 in. diam. [b] D-c, straight-polarity power source.

Table 3—Lap Welds

Bar diameter x 1/8 in.	Electrode, AWS	Position	Overlap distance	Pass sequence	Current (DCSP)[b] amp: Root pass	Current (DCSP)[b] amp: Subsequent passes
4	E7016[a]	Flat	4 x diam		120	120
4	E7016[a]	Vertical up	4 x diam		120	120
8	E7016[a]	Flat	4 x diam		140	140
8	E7016[a]	Vertical up	4 x diam		140	140
11	E7016[a]	Flat	4 x diam		160	160
11	E7016[a]	Vertical up	4 x diam		160	160

[a] Either E7016 or E7016 iron-powder electrodes may be used, 1/8 in. diam. [b] D-c, straight-polarity power source.

geometry should be aware of the loading-system disadvantages as discussed previously. The electrode choice and current magnitudes are subject to the same considerations as the butt-welding procedure. An overlap distance of 4 × diameter was found to give best results. The number of passes indicated provides an ample cross section of deposited weld metal.

For both butt and lap welds, positioning of the bars prior to joining was accomplished with a clamp supporting arrangement. Lap welds were made in both flat and vertical positions, and butt welds were made with the bars vertical.

Tack Welds

Tack welds are often used for preliminary positioning of reinforcing bars prior to encasement by the concrete. These joints must withstand a moderate amount of bumping in order to perform this nonstructural function.

Suitable tack welds were accomplished with the welding procedures outlined above for structural joining, the only difference being

Table 4—Fillet Tack Welds Between Nonparallel Bars of Similar and Dissimilar Diameters

Bar diameter x 1/8 in.	Fillet size, in.	Fillet length, in.	Current, amp 70° F Ambient	Current, amp 0° F Ambient
4 to 4	1/4	3/4	130–140	160
8 to 8	1/2	1 3/8	130–140	160
11 to 11	5/8	2	130–140	160
4 to 8	1/4	1 3/8	130–140	160
4 to 11	1/4	2	130–140	160
8 to 11	1/2	2	130–140	160

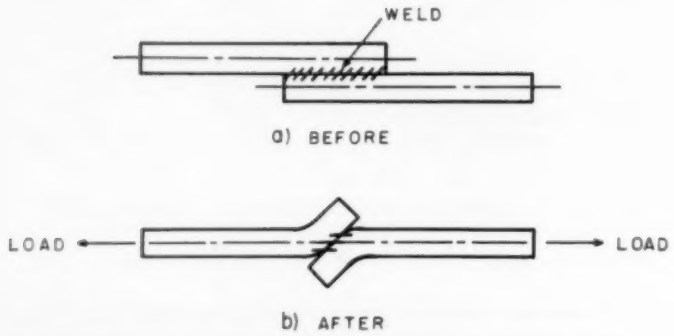


Fig. 8—Loading of lap specimens. The effects of eccentricity are shown

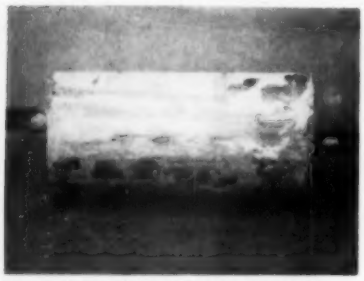


Fig. 9—Lap weld encased in concrete

weld geometry and base-metal temperature. Table 4 gives minimum tack-weld sizes for the three bar sizes. These size recommendations provided crack-free fillets which withstood a limited degree of ordinary handling loads. The minimum size requirements provide (1) enough weld metal to withstand cooling stresses, and (2) sufficient base-metal temperature increase to prevent prohibitively drastic quenching.

The fillet dimensions for the various bar sizes can be formulated as follows. The fillet size was approximately one-half the diameter of the smaller bar to be joined. The fillet length was approximately one-half the circumference of the larger bar. If rougher pre-encasement handling causes these tack joints to fail, heavier deposits can be used with no metallurgical or residual-stress difficulty.

Summary

A program has been completed on the arc welding of reinforcing bars obtained at random from various sources representing over 19 heats of various grades in bar sizes Nos. 4, 8 and 11, and embracing the following range of chemical composition: carbon—0.21 to 0.84%, manganese—up to 1.67%, phosphorus—up to 0.081% and sulfur—up to 0.067%. Although the sampling technique utilized in obtaining the material for this study did include bars from several principal domestic sources and from all reinforcing bar grades, it should be noted that the chemical composition of bars encountered in service may lie outside the range investigated.

For all the lots examined, butt welds exhibited joint strengths in excess of base-metal yield strengths, and for some analyses (intermediate and structural grades) joint strengths were within 10% of the base-metal ultimate strengths.

The most successful joint design was a butt weld with edge preparation and weld-deposition techniques chosen to provide 100% penetration, slag-free deposits. Angle-iron weld-joint reinforcement gave stronger welds in some cases. The lap-weld joint geometry was less successful except when loading eccentricity was sufficiently reduced during tension testing. Use of small-diameter bars (No. 4, 1/2 in. diam) or shallow (15-deg) double bevels are methods of avoiding appreciable eccentricity.

Low-hydrogen electrodes, E7016 or its iron-powder modification, gave satisfactory results. No preheat or post-weld stress relief was required.

Tack welds were produced which gave satisfactory resistance to ordinary handling loads. Minimum-size recommendations for tack welds are included in this report.

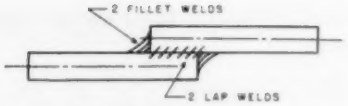


Fig. 10—End-fillet lap specimen

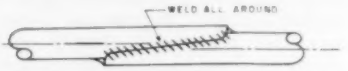


Fig. 11—Beveled lap-weld specimen. This geometry reduces eccentricity while retaining the fabrication advantage of the lap weld

Discussion

by W. Sanders, Jr., and W. H. Munse

Several years ago a brief study of the static strength of welded reinforcing bars was conducted at the University of Illinois which may add to the results reported by the authors. The tests were made on several different sizes and grades of deformed bars. Included were intermediate and hard-grade billet-steel bars in both No. 7 and No. 11 sizes and a special high-strength bar of No. 18S size (ASTM-A408–57T). The chemical compositions of these bars are given in Table A herewith.

In preparing the welded specimens for this study, electrodes were selected with a tensile strength which was matched to the ultimate strength of the base bars, except in two instances. In these two instances No. 11 hard-grade bars were welded with electrodes of unmatched tensile strength. All of the joints in the No. 7 and No. 11 bars were prepared with a single-V end preparation, but those in the No. 18S bars

W. SANDERS, JR., is Research Assistant in Civil Engineering, and W. H. MUNSE is Professor of Civil Engineering, University of Illinois.

were of a double-V type; in all cases but one, the included angle was 60 deg. A summary of these joint details is included in Table B.

In the fabrication of the joints, the welder was instructed to prepare sound joints in the horizontal position and with the electrodes and bars provided. The resulting joints were similar to those described by Messrs. Rudy, Suyama and Schwartzbart in that they were single-V and double-V multiple pass welds. However, the welding currents for the joints of this discussion were somewhat higher because the welds were deposited in the horizontal rather than the vertical position.

The results of the tests are summarized in Table B and indicate that the strengths of these joints were similar to the strengths of the joints reported by the authors for comparable materials. This similarity in behavior can be noted also in Fig. A. This figure shows the results of Table B plotted in combination with the data of Figs. 1 and 2 of the paper by Rudy, Suyama and Schwartzbart.

A further evaluation of the results can be obtained from the values of joint efficiency given in Table B. Based on the ultimate strength of the unwelded bars, Rudy, Suyama and Schwartzbart reported efficiencies of 90 to 95% for structural and intermediate-grade bars and 60 to 80% for hard-grade bars. The writers obtained efficiencies of 89 to 96% for intermediate-grade bars but also had efficiencies almost this high for hard-grade bars (the lowest value being 83% in the case of test H2). However, this latter value was for a bar welded with an electrode having a tensile strength matched to that of the base material.

The effect of varying the class of electrode can be seen in Table B in the results of tests H3 through H6. An increase in efficiency from 59 to 96% was realized in these tests by changing from an E7016 electrode to an E12015 electrode.

In one case, Rudy, Suyama and Schwartzbart report the ultimate strength of a welded bar to be only 105% of the yield point of the unwelded base material. However, this appears to have been the result of using an E7016 electrode with a hard-grade bar, a marked undermatching of materials. A similar result can be observed in the data of test H4 reported herein. However, the minimum ratio of joint strength to yield strength reported in this discussion for hard-grade bars and matched electrodes was obtained in test H2, which was conducted on a bar with a carbon content of 0.72% and a manganese content of only 0.45%. In this case the ultimate strength of the welded bar was 167% of the yield point of the unwelded base material.

Several tests were conducted also on angle connections similar to those

Table A—Chemical Composition

Grade→	Intermediate		Hard		Hard (special),
Size→	No. 7	No. 11	No. 7	No. 11	No. 18S
			Composition, %		
C	0.41	0.42	0.72	0.61	0.41
Mn	0.35	0.40	0.45	0.80	0.87
S	0.035	0.030	0.030	0.023	0.018
Si	0.11	0.10	0.12	0.13	...
P	0.011	0.017	0.012	0.011	0.013
Cr	...	...	...	...	0.99
Mo	...	...	...	...	0.19

Table B—Summary of Results of Tests

Specimen type	Bar size	Grade	Electrode	Joint	Yield point, ksi	Ultimate, ksi	Efficiency, %
I1	7	Intermediate	...	Unwelded	44.8	74.0	..
I2	7	Intermediate	E7016	60°	44.6	70.9	95.8
I3	11	Intermediate	...	Unwelded	46.6	77.8	..
I4	11	Intermediate	E7016	60°	43.4	73.6	94.6
I5	11	Intermediate	E7016	45°	39.9	68.7	88.7
H1	7	Hard	...	Unwelded	56.8	114.3	..
H2	7	Hard	E12015	60°	58.0	94.8	82.9
H3	11	Hard	...	Unwelded	57.5	107.8	..
H4	11	Hard	E7016	60°	43.0	63.4	58.8
H5	11	Hard	E9016	60°	47.9	79.7	73.9
H6	11	Hard	E12015	60°	56.6	103.4	95.9
S1	18S	Hard	...	Unwelded	90.4	124.4	..
S2	18S	Hard	E12015	60°	..	115.8	93.1

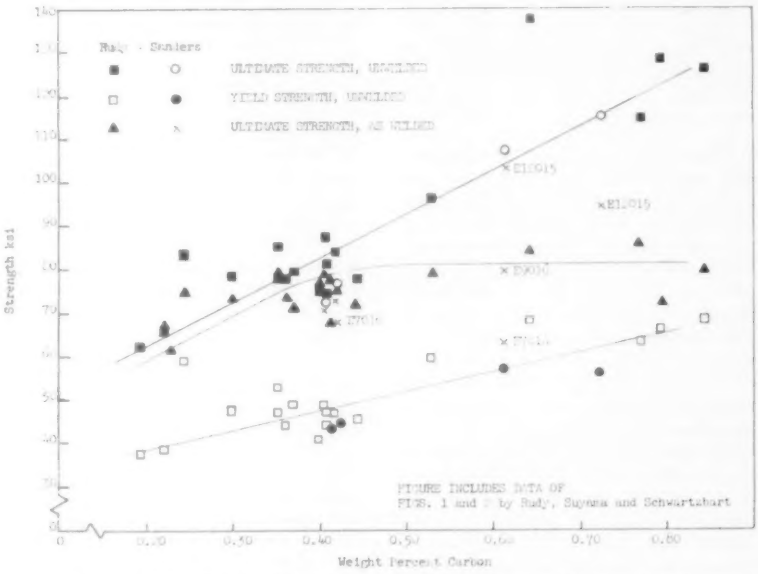


Fig. A—Additional comparisons of butt welded vs. unwelded properties

reported by Rudy, Suyama and Schwartzbart, but fabricated without a butt weld. Double fillet welds joined the bars to the angle and extended for a distance of $2^1/_2$ bar diameters in either direction from the ends of the bars. These joints developed the full strength of the bars and, as a result, suggest that it may be possible to eliminate the butt weld in the angle-type connection if the fillet welds have a length of $2^1/_2$ bar diameters.

In addition to the static test results reported herein, a series of fatigue tests was conducted on welded reinforcing bars. A report of these tests is being prepared for publication in the near future.

Discussion

by Clarence R. Rea

This is not intended as a pure discussion of the paper by Rudy, Suyama and Schwarztbart, but a discuss on of related information to emphasize certain points on the same subject.

The need to widen structures to bring them up to present day standards, or replace these structures entirely, is apparent. The Bridge Division of the Texas Highway Department felt that certain studies were necessary to prove or disprove the weldability of reinforcing steel bars of unknown chemistry before deciding to:

1. Replace the bridge entirely.
2. Remove concrete of a width necessary to provide a length of bar necessary to provide a lap splice for bond.
3. Remove only a small amount of concrete to allow the welding of new reinforcing bars to the old reinforcing bars.

Tests have proved to our satisfaction that, with proper procedures and proper inspection, reinforcing steel of new billet hard grade and of rail steel can be successfully welded. We have adopted the general practice of removal of a minimum amount of concrete and welding of the reinforcing steel to make the splice. We do not feel that it is necessary to develop the ultimate strength of each bar. Our design specifications require that the material meet the physical properties of the lowest grade of steel allowed, i.e., new billet of intermediate grade. In no case have we made tests on welded bars which did not pass the minimum ultimate requirements of 70,000 psi.

In general, our designs are such that the range of stress is low. If there is a reversal of stress, the range will not normally exceed 5000 to 6000 psi. In other designs, i.e., cantilever widening of a pier cap, there would be no reversal but a range of low stress to high stress of not over 14,000 psi.

After having established the ability to join the material to meet pure axial loadings, we further investigated the problem by running fatigue tests on welded reinforcing bars of both hard-grade and rail quality. These tests were butt welds on No. 7 rail steel and on No. 9 hard-grade new billet steel.

Because of the lack of a fatigue-type testing machine with capacity to test the large bars, each specimen was machined down to $^1/_2$ in. diam. This would, of course, eliminate any possibility of a notch effect from the full welded bar but does not eliminate any hard or brittle zone which was present because of the nature of the materials. In each case the weld was placed so that it was at the point of maximum stress.

Most of the bars were subjected to full reversal of stress ranging from approximately design stress up to approximately three times design stress. Other bars were taken from 0 stress to maximum stress with no reversal. Results of test are shown in Table C herewith.

The Texas Highway Department feels that it is fully possible to use welded connections on reinforcing steel of unknown chemistry. In using reinforced-concrete construction, we see no reason to demand anything beyond developing the yield strength of the bar since any stress beyond this would cause deterioration of the concrete before failing the steel. Beginning in about 1948 with this type of construction, we have since widened several hundred bridges (pier caps, roadway slabs and pier footings) through this method and feel that it is fully satisfactory. We have had no failures. Our specification requirements are published in Texas Highway Department Bridge Division Bulletin No. 1 which is available upon request.

Table C—Tabulation of Results

Type	Stress, psi	Cycles of stress	Type test	Failure
A	21,900	2,500,000	R	F
A	25,800	2,230,000	R	NF
A	26,800	2,100,000	T	NF
A	27,300	760,000	R	F
A	27,500	2,100,000	T	NF
A	28,700	292,000	R	F
A	30,600	666,000	R	F
A	33,200	2,200,000	T	NF
A	35,000	233,000	R	F
A	45,700	2,400,000	T	NF
G	20,300	2,131,000	R	F
G	22,100	3,266,000	R	NF
G	30,200	2,014,000	R	F
G	36,700	169,000	R	F
E	22,700	1,151,000	R	F
E	29,300	808,000	R	F
E	38,600	102,000	R	F
E	45,400	45,000	R	F
B	23,600	980,000	R	NF
B	36,400	220,000	R	F
B	50,800	21,000	R	F

Key: A—Rail steel, no preheat. B—Rail steel, 400° preheat. E—Rail steel, 200° preheat. G—Hard grade, no preheat. R—Complete reversal. T—0 to full stress—no reversal. F—Failure. NF—Did not fail. Electrodes E7015.

CLARENCE R. REA is Senior Field Engineer, Bridge Division, Texas Highway Department, Austin, Tex.

Discussion

by M. F. Couch and R. E. Somers

There are a number of important factors that must be considered in evaluating Messrs. Rudy, Suyama and Schwartzbart's research work and its potential application to commerically welded joints in concrete reinforcing bars.

1. It is stated in the abstract that "the chemical composition of bars encountered in service may be outside the range investigated." This is true for a reason not brought out in the report, namely, that the commercial specifications for concrete reinforcing bars are based, not on chemistry, but on mechanical test properties. This is illustrated, for example, in ASTM Specification A-15. It is not ordinarily intended, nor necessary, that reinforcing bars be of a weldable material. The steel producers are free to apply substantially any chemical analysis that will meet the specified tensile, elongation and bend-test requirements. This practice is quite satisfactory for the 99% of reinforcing bars which are not arc welded. On the other hand, if welded joints are to be used, the chemical analysis is of primary importance. The obvious solution is to obtain an analysis of any lot steel that is to be welded, then specify the welding procedure accordingly. This approach has been adopted in the as-yet unfinished recommendations of the AWS Building Code Subcommittee on Welding Reinforcing Bars.

2. According to Table 1, "Chemical Composition of Steels," only five of the 19 lots of bars used in the authors' tests fall within the range 0.53 to 0.84% carbon, where welding problems are known to be most severe. We would hesitate to draw conclusions from these few tests, which, even according to the authors, may not represent the most difficult-to-weld materials that may be encountered in the field. The authors imply that high-carbon material can be welded satisfactorily merely by using low-hydrogen electrodes. All of our experience points in the opposite direction.

3. In the Summary on page 340-s, it is stated: "No preheat or post-weld stress relief . . .was required." However, on page 339-s it is stated: "With this procedure (that used for the test welds) the base-metal temperature in the weld area was approximately 200° F just prior to the second bead, and 300° F prior to all subsequent beads." Since the reason for preheating is to retard the cooling rate of the weld, it would appear that the test joints had the advantage of preheating. It is unrealistic to suggest tht the authors' laboratory results in which there was, in effect, preheat, could be duplicated under field conditions without preheat.

4. In the last sentence of the Introduction, it is stated: "Therefore, a weld that allows the steel to be loaded to its yield point is adequate." Under this criterion of acceptance, the welded joint need not develop the minimum tensile strength of the base metal, as required by the current 1946 AWS "Standard Code for Arc and Gas Welding in Building Construction." (See paragraphs 106, 601b, and D109.) Paragraph 106 requires the use of ASTM A7; 601b says unless the joints and procedure to be used are exempt they must be qualified under the AWS Standard Qualification Procedure; D109 says the tensile strength of the reduced-section tensile test of the procedure qualification shall not be less than 60,000 psi, which is the minimum for A7 material. The 1950 edition of the AWS Standard Qualification Procedure says the tensile strength shown by the reduced-section tensile tests shall be not less than 100% of the minimum of the specified tensile range of the base material used. Brittle, porous and even cracked welds can reach the yield point of the base metal before failure in a simple static tensile test. It is significant that, in Table 1 of the report, no elongation is reported for specimens Hd-2 and Hd-3, even though their yield strength was from 62,000 to 68,000 psi. It is quite possible that joints of this type could be broken in handling, or during placing or vibrating of the concrete. Moreover, winter conditions in the field would reduce the ductility of the completed joint even below the level measured by the laboratory tensile tests made at room temperature. We do not believe that designers, engineers and code-writing groups would, or should, accept the mere development of the yield strength of the base material as a standard for the procedure qualification for welded joints.

Summarizing, the writers consider that it would be extremely dangerous to apply the authors' suggested welding procedure (low-hydrogen E70XX electrode, no preheat) to reinforcing bars of unknown analysis, or to any analysis for which we know that procedure to be unsuited. We do not see any reason why accepted standards and procedures for good welding practice should be ignored in welding concrete reinforcement. The writers hope that no one will conclude from the authors' paper that this may be done just because the material to be welded is in reinforcing-bar form.

M. F. COUCH is Welding Engineer, and R. E. SOMERS is Division Head, Research Department, Bethlehem Steel Co.

Authors' Closure

We are happy to receive the discussions presented by Sanders and Munse, Rea, and Couch and Somers, and especially the former, because of the additional data which they have supplied. Since the welding of reinforcing bars is so highly controversial, more light in the form of data is needed rather than more heat, so that conclusions may be drawn from the results of many investigations, rather than from a few scattered tests or, what is worse, from unconfirmed opinion or legend. We are especially anxious, therefore, that the results of all experimental programs in this field be made public, so that the best conclusions possible may be drawn.

Now, specifically in regard to the discussions, it is interesting to note the general agreement between our results and those of Sanders and Munse. In reference to one particular point, they show a marked improvement by matching electrode to base-material strengths whereas the improvement we showed was not universal; further, we showed an increased susceptibility to scatter. The reason for using a single electrode on all materials in our program is that it was presumed that the bar composition would be unknown at the time the welding was done.

Couch and Somers in their points one and two are essentially raising the question of how representative, in chemical composition, our sample of bars was in relation to the population of reinforcing bars in service.

In reply, we can only state that an accepted statistical approach was used to get our samples; they were obtained at random from several suppliers and from several grades. It would appear that the question of how representative our compositions are of the actual compositions in service can only be answered by a large scale statistical sampling program, which would then indicate the probability that a steel of any composition range might be encountered in, let us say, widening a particular bridge.

Further, contrary to the discussors' point 2, it was brought out in the paper that "reinforcing bars are classified as either structural, intermediate, or hard grade from low to high carbon content. The separation is made on the basis of a yield strength rating. . . ."

In regard to point 3, it is correct, as was stated in the paper, that interpass temperature was higher than room temperature and this can have the effect of preheat for passes after the first one. However, it is also correct that preheat or postweld stress relief, according to their AWS definitions, was not required. This was further borne out by a series of experiments which were not reported in the paper in which the bars were cooled to room temperature after each pass. The properties of those welds were the same as those not cooled, no deleterious effect being observed on the welds so cooled between passes.

In Couch and Somers point 4, they object to our statement that "a weld that allows the steel to be loaded to its yield point is adequate." They cite as support for their objection the AWS "Standard Code for Arc and Gas Welding in Building Construction" which they state requires a welded joint to develop the minimum tensile strength of the base metal. We have examined the AWS code and interpret what we read as follows:

First of all, the code does say that a welded joint shall not be stressed in excess of the *allowable* stress for the base metal. Now, what is the allowable stress? Let's refer to the codes which govern the construction of reinforced-concrete structures. The "American Concrete Institute Building Code" says that steel for concrete reinforcement shall not be stressed in tension in excess of 20,000 psi for rail-steel concrete reinforcing bars, billet-steel concrete reinforcing bars of intermediate and hard grades, axle-steel concrete reinforcing bars of intermediate and hard grades, and 18,000 psi for billet-steel and axle-steel reinforcing bars of structural grade. The "Standard Specifications for Highway Bridges" adopted by the American Association of State Highway Officials says that the maximum allowable stresses for steel reinforcement in tension in flexural members are 18,000 psi for structural grade, and 20,000 psi for intermediate grade. The strength of the welds on this program exceeded these allowables by a very considerable margin, i.e., by factors of three and four.

Further, 601b and 601a of the AWS Code does require qualification procedure unless the joints and procedures conform in all respects to the provisions of Sections 2, 3, and 4. A realistic consideration of Sections 2, 3 and 4 indicates that the welding procedures used in this program conform with these Sections, and are, therefore, exempt from qualification procedure. However, assuming they are not, Couch and Somers state that D109, the qualification procedure, requires that the tensile strength of the reduced-section tensile test shall not be less than 60,000 psi, which is the minimum for A7 material. Reference to Figs. 1 and 2 of the paper shows that this requirement has also been met.

In summarizing the reconciliation of the results of this program to existing codes, it seems to the authors that no case can be made for the argument that the current results do not comply with the existing codes.

WRC BULLETIN NO. 51

Reinforced Openings on Pressure Vessels

Welding Research Council Bulletin No. 51, published in June 1959, contains four papers describing research work sponsored by the Pressure Vessel Research Committee of the Welding Research Council. Projects were carried out under the guidance of the Subcommittee on Reinforced Openings at Pennsylvania State University, the University of Illinois and Yale University to determine the stress concentration effects around various designs of reinforced openings of pressure vessels in an effort to develop improved designs. Price $2.00. Single copies may be purchased through the American Welding Society, 33 W. 39th St., New York 18, N. Y. Quantity lots may be purchased through the Welding Research Council, 29 W. 39th St., New York 18, N. Y.

The first paper in the Bulletin was a theoretical analysis written by Prof. E. O. Waters of Yale University. Photoelastic tests on scale models of spherical vessels with attached nozzles of various shapes were made at the University of Illinois while full-size steel pressure vessels having welded branch connections were tested at Pennsylvania State University. The second and third papers describe these investigations. In addition, a fourth paper on unreinforced openings was included as a basis of comparison.

WELDING CLINIC

J. Imperati and R. F. Pulver, Welding Engineers
The American Brass Company, Waterbury, Conn.

Give worn equipment a new lease on life by surfacing with Anaconda Welding Rod

Anaconda Welding Rods are widely used in production and maintenance operations in the manufacture of all types of mechanical equipment and consumer goods. Familiar uses are the joining of iron and steel parts by oxyacetylene braze welding and the oxyacetylene braze-welding repair of broken machine parts. Of equal importance is their value in overlaying iron and steel to reduce the friction of sliding surfaces, and in rebuilding worn surfaces to get continued usage from parts that would otherwise be scrapped. Anaconda-997 (Low Fuming) Bronze, Tobin-Bronze 481, and Nickel Silver-828 Welding Rods are useful for many such applications.

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3. *Economy in time* . . . frequently repair welds are made without dismantling equipment.

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5. *Absence of iron pick-up* in deposits made on iron and steel, thereby avoiding hard spots and cracks.

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